

THE INFLUENCE OF DIFFERING DEGREES OF CLOSURE ON INTEGRAL AND  
FOCUSED ATTENTION TASKS USING OBJECT DISPLAYS

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by

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## ABSTRACT

### THE INFLUENCES OF DIFFERING DEGREES OF CLOSURE DURING INTEGRAL AND FOCUSED ATTENTION TASKS USING OBJECT DISPLAYS

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The present study serves as a follow-up to a thesis conducted by Jeffrey Schmidt of the University of Dayton. Schmidt (1992) proposed that using an object display formed by the Gestalt Law of Closure would provide a dual benefit over a normal object, and bar graph display. The results only partially supported this hypothesis. One possible explanation for the result had to do with the size of the space between the triangle vertices in the closure display. Therefore, this study attempted to answer whether there is an optimum amount of space between the triangle vertices that would increase focused attention performance, while still maintaining the subjective contour for integral task performance. Two variables were manipulated to decide the best format for presenting different types of information on an object display. One variable was display type (bar, object, 16% closure, 33% closure, and 66% closure) which was manipulated between participants. Task type, integral or focused attention tasks, was manipulated within participants. The 33% closure, the bar graph, and the object display served as controls that were used in Schmidt's study. Percentage correct (strict and lenient), absolute error and reaction time measures all served as the dependent variables in this study. Planned comparisons and Analysis of Variance analyses were conducted on the data. The results did not support the dual benefit hypothesis of the closure display, as presented in Schmidt (1992).

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## TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT.....	iii
ACKNOWLEDGEMENTS.....	iv
LIST OF FIGURES.....	vii
LIST OF TABLES.....	viii
INTRODUCTION.....	1
Compatibility of Proximity Principle.....	2
Emergent Features.....	2
Object Versus Separable Displays.....	4
Subjective Contours.....	6
Empirical Basis for Present Study .....	8
Present Experiment.....	12
Display Formats .....	12
METHOD.....	14
Participants.....	14
Design .....	14
Displays.....	14
Apparatus.....	14
Procedure.....	15
RESULTS.....	17

DISCUSSION.....	29
Interpreting Results at Face Value .....	30
Present Study versus Schmidt (1992).....	31
Possible Explanations for Results.....	33
Implications for Further Research.....	35
Summary .....	36
APPENDICES .....	38
A   Participant Instructions and Debriefings .....	38
REFERENCES.....	58

## LIST OF FIGURES

<u>Figure</u>	<u>Page</u>
1     Rectangle object display used by Wickens and Andre (1990).....	6
2     A subjective square (Laurie, Warm, Dember, and Frank, 1994).....	7
3     Displays used by Schmidt (1992).....	9
4     Formation of an imaginary triangle (Schmidt, 1992).....	10
5     Display formats for Canaras (1996).....	12
6     Task parameters on displays used by Canaras (1996).....	16
7     Mean strict percent correct for focused tasks.....	19
8     Mean strict percent correct for integral tasks.....	19
9     Mean strict percent correct as a function of display and question.....	20
10    Mean lenient percent correct for focused tasks.....	21
11    Mean lenient percent correct for integral tasks.....	21
12    Mean lenient percent correct as a function of display and question.....	22
13    Mean absolute error for focused tasks.....	23
14    Mean absolute error for integral tasks.....	23
15    Mean absolute error as a function of display and question.....	24
16    Mean reaction time (ms) for focused tasks.....	25
17    Mean reaction time (ms) for integral tasks.....	25
18    Mean reaction time (ms) as a function of display and question.....	26

## LIST OF TABLES

<u>Table</u>	<u>Page</u>
1 Means and standard deviations for all conditions.....	18
2 Statistic summary table for planned comparisons.....	27
3 Summary table for ANOVA statistics.....	28



## INTRODUCTION

Many jobs in today's society require supervisors to integrate several pieces of information to make an informed decision. These jobs may also require supervisors to separate information from a display to make a decision about a specific variable that may affect the system, while ignoring extraneous information. Respectively, these two tasks are labeled: (1) information integration, and (2) focused attention. Therefore, a display needs to be established that would enable supervisors to perform both these tasks effectively.

The process of integrating multiple sources of information and retaining the accessibility of the separable information is a difficult task. An example would include monitoring the safety system at a nuclear power plant. An integration task would require the operator to combine several pieces of information to diagnose the current system state. In the case of a nuclear power plant, information including such parameters as the level of coolant, core heat removal, secondary heat removal, reactivity control, and contaminant integrity must all be considered in determining the current system state. However, assessing the status of a particular parameter, such as the coolant level, is a focused attention task and requires the operator to separate vital from extraneous information (Woods, Wise, and Hanes, 1981).

One type of display evaluated as a potential solution to this problem is referred to as an object display. As defined by Carswell and Wickens (1987) "an object display refers to any graphical technique that uses several dimensions of a single perceptual object to present multiple sources of information (p. 511)." In other words, several parameters of a system that otherwise would have been found in separate displays are integrated into one display. The opposite is true for separable displays; different sources of information are located on separate displays. Research that has investigated object displays has been primarily concerned with comparing the benefits of integral versus separable displays. Before we discuss these benefits there are a few principles that must be addressed first: (1) the

compatibility of proximity principle, and (2) the concept of emergent features. Both are discussed in the following sections.

### Compatibility of Proximity Principle

Garner (1978) provided the theoretical basis for the compatibility of proximity principle. This principle states that the variables should be integrated physically or proximately in accordance with how the operator processes the information. Tasks that require the integration of multiple sources of information are said to have close mental proximity. Such tasks will be performed more accurately when using a highly proximate display in which information is close together, or combined. However, tasks that require the focusing of attention on a particular variable are said to have low mental proximity. Such tasks will be best served by more separable displays (Wickens and Andre, 1990; Barnett and Wickens, 1988; Carswell and Wickens, 1987).

There is support for this principle. Primarily, experiments compared the effect of bar graphs and object displays on the performance of both focused attention and integration tasks. Carswell and Wickens (1987) found an advantage for the object display when the task required integrating information; as the degree of information integration decreased, the separable display (bar graph) became more efficient. This conclusion was partially supported by Barnett and Wickens (1988) who found that during the integration task participants in the object display condition performed better than the participants in the bar graph condition. The predicted cost of the object display during focused attention tasks was not found; the bar graphs were not significantly superior to the object displays during these tasks. Thus, there may be a possibility of another principle working besides that of compatibility of proximity.

### Emergent Features

Relations between individual line segments may result in what is referred to as an “emergent feature” (Pomerantz and Pristach, 1989). Thus, the perception of a triangle does

not consist of individual segments, but rather it consists of the interactions of the line segments that are formed from the intersections (local features) and closedness (global features) of the figure (Pomerantz, Sager, and Stoever, 1977).

Since emergent features form a recognizable shape (i.e., a triangle) it is easy to mentally combine several parameters to diagnose a system. If the parameters do not combine to form the proper shape, then the operator knows that there is something wrong with the system. Therefore, emergent features have been linked to good performance when the task requires integration of information. However, emergent features are not necessarily limited to object displays. It has been found that a separable bar graph with a strong emergent feature could support an integration task better than an object display (Sanderson, Flach, Buttigieg, and Casey, 1989; Buttigieg, Sanderson and Flach, 1988). This could occur if the midpoints of the bars on the bar graph created the emergent feature of linearity, as in Sanderson et al.'s (1989) experiment. These results are contrary to the proximity of compatibility principle in that we do not need a highly proximate display for an integrated task (Buttigieg et al.). However, Bennett, Toms, and Woods (1993) compared configural and bar graph displays using both integral and focused tasks. Configural displays are designed to facilitate both integral and focused attention tasks. They found that the configural display, which highlighted low-level data, had an advantage on integrative tasks. There was no difference in performance on the focused attention tasks; however there was a significant cost in latency with the configural display. Bennett et al. also noted that to support the focused attention tasks, the elements in the object display should be made more noticeable. This may be accomplished by using techniques such as spatial separation and color coding.

Now that the general principles surrounding the use of object displays have been established, the specific costs and benefits surrounding both object and separable displays will be discussed in the following section.

### Object Versus Separable Displays

Wickens and Andre (1988) identified several benefits to the object display. First, object displays can reduce the amount of display clutter that could be caused by having many variables distributed across separate displays, resulting in more economical use of display space. Second, because of the highly parallel nature of the early visual system, object displays allow us to process all the individual attributes in parallel to rapidly discern the state of the system. Finally, in accordance with the proximity of compatibility principle, tasks that require high mental integration will benefit from close proximity.

Despite the benefits, there seems to be a cost associated with object displays in regards to the proximity of compatibility principle. As noted before, object displays tend to be more beneficial during integration tasks, but not as effective during focused attention type tasks. However, the results have been mixed regarding the costs associated with using an object display for focused attention tasks.

Carswell and Wickens (1987) researched the benefits of the object display in both integrative and focused attention tasks, so they could ascertain the types of tasks for which object displays are more suited than the bar graph display. They compared a triangle object display with that of a bar graph display in both integrative and focused attention type tasks. In the integrative tasks, the participants were instructed to monitor the pressure of two input parameters, and to detect any system failures. This was an integrative task because they were instructed to average the values of these parameters and make certain that the associated output value was not significantly higher or lower than the mean. The focused attention task used in this study required the participants to monitor six different parameters, and the task was to indicate if a given parameter moved passed a certain point on the scale. Carswell and Wickens found that the object displays supported better performance on the integrative tasks, whereas the bar graph display was shown to be superior in the focused attention type tasks.

Casey (1986) also attempted to determine how the participant perceives and integrates information. Casey's participants had to monitor the status of a heating system by relying on the temperature information contained in five separate chambers. Casey compared three types of displays that presented this information: schematic face, polygon, and a bar graph. The schematic face display, otherwise known as the Chernoff display, is a type of object display, whereas the polygon display is more of a traditional example of an object display. However, the bar graph display is not considered an object display, but rather as a separable display.

The schematic face display used ear length, eyebrow angle, eye length, nose length and mouth curvature to represent the temperature in each of the five chambers. If the face was "happy" and had short features, the variables were all at low levels, and if the face was "sad" and had long features the variables were all at high levels. The task was considered a detection task which would be equivalent to the focused attention task in Carswell and Wicken's (1987) study. Casey found that separable displays supported focused attention tasks, but showed object and face displays had little or no effect on detection performance.

The cost associated with an object display has been suggested to result from trouble decomposing the object display to evaluate the individual attributes, which is a necessary function of focused attention tasks. This notion, as described by Pomerantz & Pristach (1989), is referred to as "perceptual glue" which states that low-level data are glued together to form an object and therefore are not attended to individually. However, some studies have suggested that there is not as much of a cost as some believe. A reason, offered by Bennett et al. (1993), for finding such a cost is due to the fact that the research has been biased toward finding one. In other words, much of the research has focused on finding costs with configural displays, rather than exploring methods of increasing the salience of low level data. As mentioned previously, Barnett and Wickens (1988), did not find a significant difference between the bar and object displays during focused attention



tasks, which was possibly due to the emergent feature of a rectangle. In other words the emergent feature may facilitate integral performance without disrupting memory for the individual features on focused tasks. Therefore, emergent features may be the key to discovering a method that imposes little or no cost of object displays on focused attention tasks.

Wickens and Andre (1990) also researched the cost of object displays, but they used a different type of rectangular display than Barnett and Wickens (1988). Wickens and Andre's (1990) rectangle was not fully enclosed; other low level parameters of the display partially formed the borders of the rectangle (see Figure 1). The object display with an emergent feature was shown to be more effective than the bar graphs in both the focused attention and integrated tasks. This effect may be due to the law of closure, which states that people perceptually fill-in incomplete contours to perceive the form as an object. Therefore, closure may be a possible emergent feature (Coren, Porac and Theodor, 1986).

### Subjective Contours

Subjective contours (see Figure 2) are lines or edges that are perceived where none physically exist (Coren, Porac, and Theodor, 1986). One characteristic of subjective contours is that the area inside the subjective contour appears brighter than the outside, thus forming a subjective border (Coren et al.; Kaniza, 1976). Although these contours seem real, they are unstable (Laurie, Warm, Dember, and Frank, 1994). The vividness of the

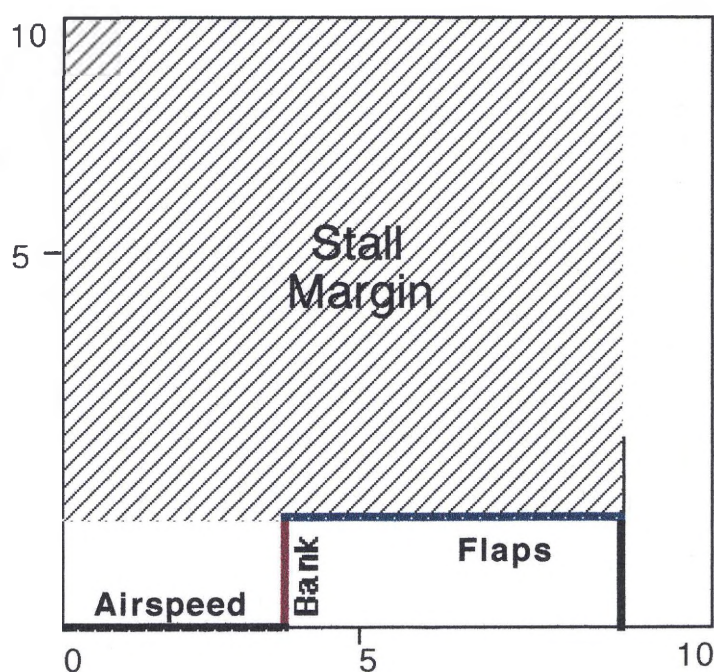


Figure 1. Rectangle Object Display used by Wickens and Andre (1990).

subjective contour has been shown to vary directly with an increase in size, while increasing luminance and contrast have little effect on vividness (Laurie et al.). When the subjective contour was perceived as unstable, the entire subjective contour faded at once. Therefore, when the subjective contour is vivid, the emergent feature may be perceived and therefore may increase performance on integral tasks.

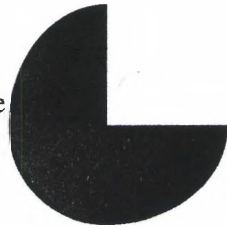
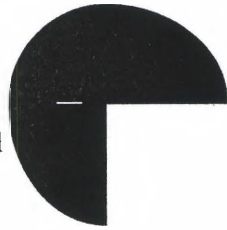


Figure 2. A subjective square (Lauri, Warm, Dember, and Frank, 1994).

When the subjective contour is not vivid, the emergent feature is not as vivid and thus performance on focused attention tasks may increase. Therefore, the unstableness of the contours may allow the operator to perform both integral and focused attention tasks with the same display.

Coren's theory states that subjective contours emerge when the observer reorganizes the given shape based on implied cues given by the experimenter (Coren et al., 1986). This supports the contention that subjective contours are unstable. Coren tested this theory by having a subjective contour that could either be perceived as a circle or a square. He then gave the participants instructions and alluded to the subjective contour as being a "figure," "square," or "circle." The participants perceived the contour to be in the shape of what the instructions implied. Therefore, the contour could be perceived in different ways depending on the instructions given (Coren et al.; Purghe and Coren, 1992).

In the present experiment, the operator will attempt to decipher the display as an object, or as separable dimensions depending upon the task instructions given (integral or focused attention).

These two experiments suggest that an object display with subjective contours could lead to higher levels of performance for both focused attention and integrated tasks. The fact that subjective contours are unstable could allow the creation of a single display that supports both focused attention and integral tasks. The figure could be considered an object or separable display depending on the specific task (integrated or focused attention) that is delegated by an implied cue. Therefore, if the participants are given a focused attention task, they will focus on one part of the display and the subjective contours should disappear. If the participants are given an integrated task, they will tend to look at the whole figure and the subjective contour should appear. The stableness of the figure can also be manipulated by increasing or decreasing gap length. Thus, one purpose of this experiment is to find the appropriate length of the gap between line segments in a closure figure that will allow both tasks to be performed efficiently with little cost.

#### Empirical Basis for Present Study

The present study serves as a follow-up to a thesis conducted by Jeffrey Schmidt (1992) for the University of Dayton entitled, "The influence of closure, color, and decision statistic on integral and focused attention task performance using object displays." The purpose of the thesis was to examine specific factors to determine which promoted better focused attention performance without imposing a cost to integration performance. Specific factors that were chosen for Schmidt's thesis were display type, and color coding; both were suggested in Wickens and Andre (1990) to increase separability. Schmidt also studied the effect that the correlation between the decision statistic and emergent features had on performance. Decision statistics are formulas that are used by the participants to ascertain the status of the system. Finally, Schmidt used both focused attention and



integral tasks as a within-subject variable. It was hypothesized that the closure display (see Figure 3A) would provide a dual benefit. In other words, when the participant focused on a single vertex of the triangle, the subjective contour would disappear. This is proposed to enhance performance on focused attention tasks over the object display (see Figure 3B). The closure display was also hypothesized to increase performance over the bar graph (see Figure 3C) display during integral tasks. This is due to the phenomenon that the subjective contour would be perceived if the participant was trying to integrate

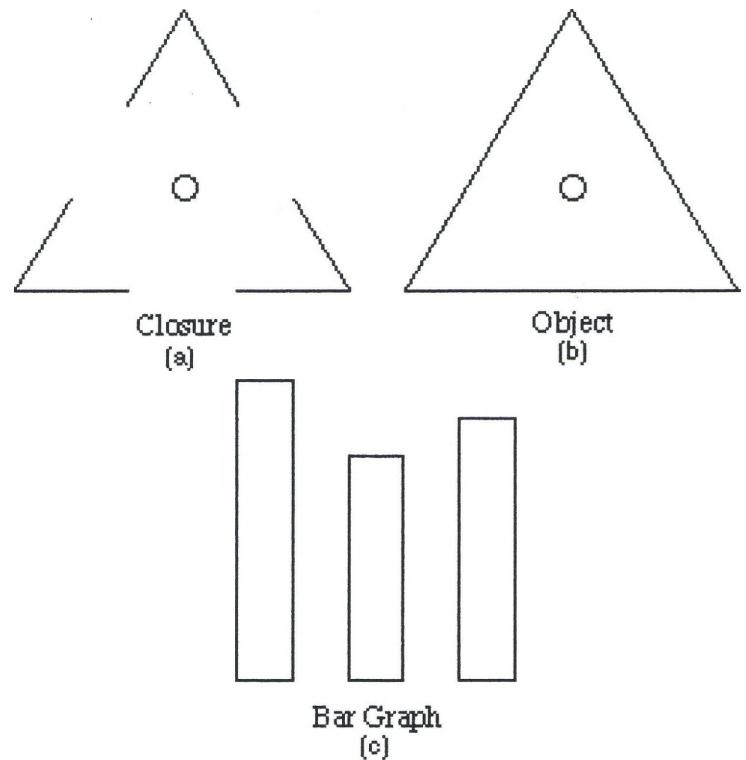


Figure 3. Displays used by Schmidt (1992).

Schmidt (1992) compared three display formats (see Figure 3): (a) a triangle formed by closure (removed middle third of each side), (b) an enclosed triangle, and (c) a bar graph. Each vertex of the triangle, or bar on the bar graph represented one parameter that was to be considered in the participant's decision. There was a zero-reference point in the middle of the object and closure displays. These same zero points also served as a frame of reference for the focused attention tasks. Dolan, Elvers, and Schmidt (1991) demonstrated that the presence of a fixation point reduces the reaction time for separable tasks when an object display was used, however it was at the cost of integral task performance.

Color was also manipulated in Schmidt's (1992) study. Each bar on the bar graph,

and each vertex of the triangles was a different color. This is denoted as the color condition. For the black and white conditions, all the vertices and bars were displayed in the same color.

There were two conditions for the decision statistic: (1) the decision statistic correlated perfectly with the triangle area, and (2) the decision statistic was imperfectly correlated with the triangle area.

The scenario used for Schmidt's (1992) study required the participants to imagine themselves as medical technicians. They monitored the display that consisted of heart rate, blood pressure, and temperature parameters. The purpose of the experiment, as described to the participants, was for the participants to detect "Schmelters Syndrome," which was considered a potentially lethal condition that could arise in the patient during surgery. The

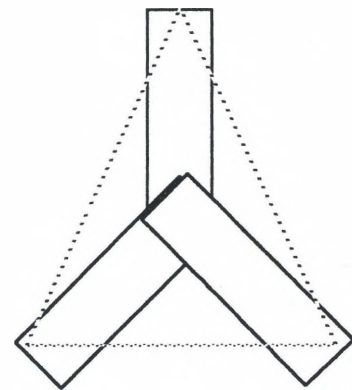


Figure 4. Formation of an imaginary triangle (Schmidt, 1992).

The participants estimated a particular parameter value for focused attention tasks, and estimated the area of the display for the integration task. In the bar graph condition, the area was estimated by imagining the bars of the graph radiating from a central point. The ends of the bar were then mentally connected to form the triangular object (see Figure 4).

Schmidt's (1992) results revealed that color had a limited effect on separability, and did not significantly alter performance on integral tasks. Color also did not increase the perception of separability for the closure or object displays during focused attention tasks. However, color did not prove to have an adverse effect on performance either. The degree of correlation of the decision statistic and emergent feature in the triangle display did not affect focused attention performance, which was hypothesized. During integral tasks a perfect correlation was found to result in better performance as compared to an imperfect

correlation; participants made more rapid and accurate responses when perfect correlation existed. Therefore, when designing a display the emergent feature should correlate with the system parameter's relationship as much as possible. However, the mapping of emergent features to the display statistic may be difficult because many object displays have more than one emergent feature, and it would be hard to ascertain which emergent feature(s) the observer is using.

Schmidt's (1992) results partially supported the hypothesis of a dual benefit of the closure display. The means revealed that the closure display ( $M=6.40$ ) had a higher percentage correct during the integral tasks compared to the object ( $M=5.15$ ) and bar graph displays ( $M=5.55$ ). However, the reaction times were fastest with the object display ( $RT=1753$  ms) followed by the closure ( $RT=1776$  ms), and then the bar graph display ( $RT=1794$  ms). During focused attention tasks, the bar graph ( $M=12.58$ ) had the highest percentage correct followed by the closure display ( $M=9.20$ ), and finally the object display ( $M=7.95$ ). The participants in the bar graph display condition also had the fastest reaction times ( $RT=1756$  ms) during the focused attention tasks, followed by object display ( $RT=1823$  ms), and then closure display ( $RT=1835$  ms) participants. Therefore, a dual benefit of the closure display over the bar graph is not fully supported. According to Schmidt, a possible explanation for this result may be related to the size of the space between the triangle vertices. Schmidt believes that a threshold may exist for the space that is needed to increase the perception of separability among the vertices. In other words, there may be an optimum amount of space between the triangle sides that would increase focused attention task performance, while still maintaining the subjective contour for integral task performance. As described previously, Schmidt formed the closure display by removing the middle third of each side of the triangle. Therefore, a dual benefit may still exist if the gaps between the vertices of the triangle are manipulated.

## Present Experiment

The present experiment will attempt to answer the question of whether increasing or decreasing the gaps of the triangle's sides will have a differential effect on focused and integral task performance. Since color was found not to have a significant effect on performance in Schmidt's (1992) study, only black and white displays will be used for the present study.

### Display Formats

Five display formats (refer to Figure 5) are to be used for the present study: (1) a triangle that has a 16% gap of each side, (2) a 33% gap of each side, (3) a 66% gap of each side, (4) an object display, and (5) a bar graph display. As in Schmidt (1992), a zero reference point is provided in each display to give participants a frame of reference. Each vertex of the triangle is represented as a parameter in the scenario of a medical diagnosis.

The 33% gap, the object, and bar display conditions serve as control

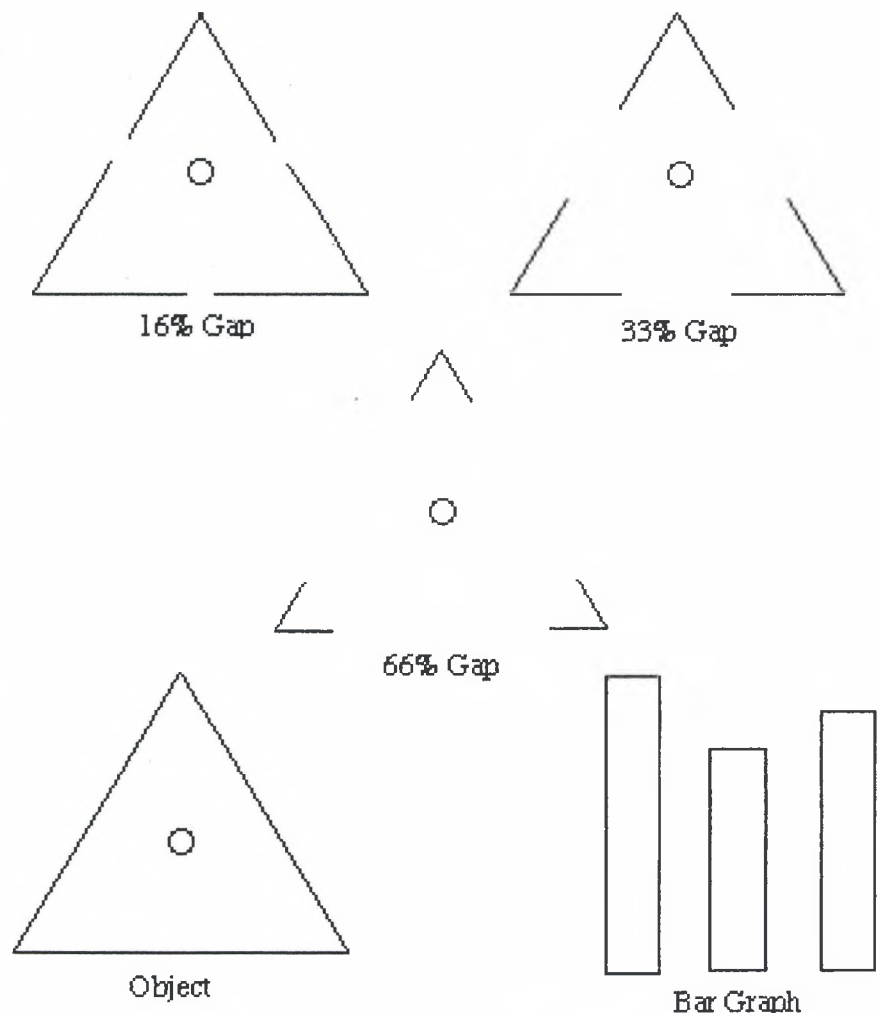


Figure 5. Display formats for Canaras (1996).

conditions because they are the same displays used by Schmidt (1992). The 33% gap display, is hypothesized to produce a dual benefit. The 33%, and the 16% gap displays are predicted to have a higher percentage correct performance and faster reaction times for integral tasks in comparison to the 66% gap display. This is because it will be easier to perceive the subjective contours, thus increasing performance on integral tasks. During focused attention tasks, the 33% and the 66% gap displays are predicted to have a better percentage correct and faster reaction times than the 16% gap display. This result is expected because it will be easier to focus on the individual parameters, thus ignoring the subjective contour.

However, there is an alternate view on how the results are predicted to turn out. One could predict that the bar graph display should have faster reaction times, and a higher percentage correct than the object and closure displays for focused tasks. This is predicted because the bar graph display is the most separable of the displays. However, the object and closure displays should not be found to differ significantly from one another based upon the theory of task dependence. In other words, the object and closure displays all require the participant to make judgments on the amount of distance the triangle vertex is from the center point. Therefore, since all the triangle displays require the participants to essentially perform the same task, accuracy and reaction time measures for these tasks should not differ significantly.

During the integral tasks it could be predicted that the object and closure displays should have faster reaction times and a higher percentage correct than the bar graph display. This hypothesis is based on the fact that the bar graph condition requires the participant to perform many more mental computations to assess the area of figure. Therefore, one may predict that the participants in the bar graph condition may take longer to respond and make more mistakes than any of the triangle displays (object and closure) during integral tasks.

## METHOD

### Participants

There were 55 participants selected from the subject pool at the University of Dayton for this experiment. They were given an hour of credit toward an Introductory Psychology research requirement for their participation.

### Design

There were two types of analyses conducted on the data. The first consisted of planned comparisons which compared: (1) bar versus 66% gap display, (2) 66% versus the 33% gap display, (3) 33% versus the 16% gap display (4) the 16% gap versus the object display, and finally (5) the bar graph display versus all the other displays combined.

The other analysis was a 5 (display type)  $\times$  2 (question type) mixed Analysis of Variance (ANOVA). These analyses were conducted for the purpose of determining if there were differences between focused and integral tasks and whether the two independent variables interact.

### Displays

Schmidt's (1992) scenario was utilized for the present experiment. This scenario asks the participants to play the role of a medical technician who has the job of monitoring a display. They had two types of tasks: to detect the presence or absence of "Schmelters Syndrome", which was described as a potentially lethal condition and to determine the value of a parameter. Each parameter of the display was represented as a separate vertex of the triangle. The parameters that were used in this experiment were: heart rate, blood pressure, and temperature. Refer to Figure 6 for how these variables will be represented on each display.

### Apparatus

A NCR 3230 PC compatible with VGA color monitor (35.56 cm diagonal measure) was used to present trials, and record data for each participant.



### Procedure

Each participant was randomly assigned to a display format: bar graph, object, 16% gap, 33% gap, or 66% gap displays . All participants received both types of tasks. There were two blocks consisting of 48 practice trials, thereby allowing for ten minutes of practice time. There was also 4 blocks of 48 experimental trials each, which consisted of the other 25 minutes of the experiment.

When the participants arrived, they were given an informed consent form to sign. Once this was signed, they were led into an enclosed room and seated in front of a personal computer. At this time, the experimenter read the instructions and conducted practice trials, which were identical to experimental trials, to make certain that the participants understood their task. After the experimenter answered any questions, she left the room to let the participant complete the experimental trials.

Each participant received only one of the five displays, and a prompt centered below. Parameters were associated with each vertex or bar of the display (see Figure 6). However, these labels were not presented during the experiment; the participant had to remember their position. The display and prompt was presented to the subject for a total of 3.5 seconds, with an inter-trial interval (ITI) of 0.5 seconds. Randomization of display type occurred across participants.

During the focused attention trials, their prompt had the name of one parameter (“HEART,” “PRESSURE,” or “TEMPERATURE”), and the task was to estimate the value of that particular parameter (between 0 and 9). Participants were instructed to estimate the individual parameters by judging the distance between the vertex and the center point. The integral task always had the word “SYNDROME,” below the figure, which required them to estimate the area of the figure. Any time during the 3.5 second interval, the participant entered a value (between 0 and 9) as their estimate of the syndrome value. The (ITI) was 0.5 seconds; the same as the focused attention trials. The

tasks randomly occurred within-participants. There was a one minute break between each block of trials.

At the end of each trial the participant received feedback for one second. If the participant's response was correct they saw the words, "CORRECT, THE VALUE IS \_\_ YOUR PATIENT

IS IN GOOD HANDS." If their response was incorrect they saw, "INCORRECT, THE VALUE IS \_\_ WATCH YOUR PATIENT CAREFULLY."

At the completion of the experimental trials, the experimenter debriefed the participants as to the nature and expectations of the experiment.

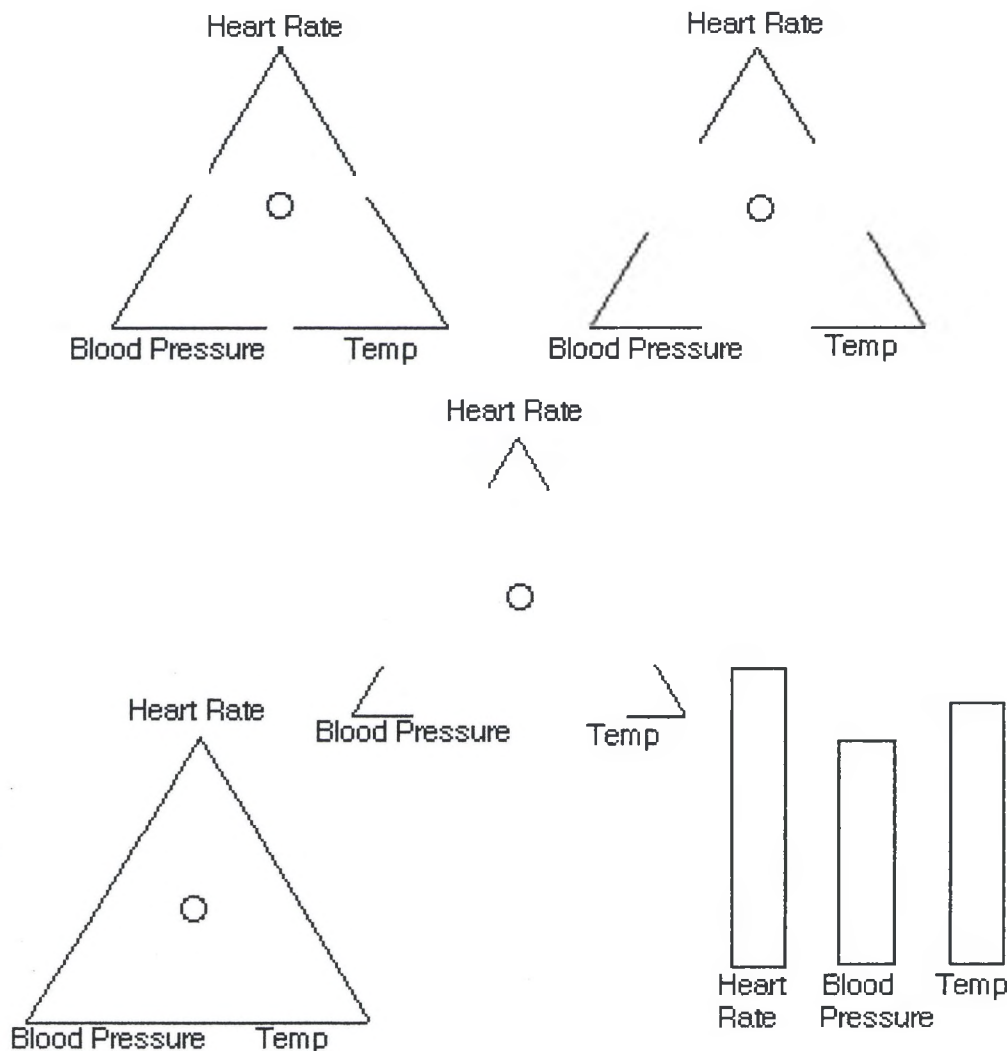


Figure 6. Task parameters on displays used for Canaras (1996).



## RESULTS

The data were analyzed by using planned comparisons. There were five comparisons analyzed for this experiment: (1) bar versus 66% gap display, (2) 66% versus the 33% gap display, (3) 33% versus the 16% gap display (4) the 16% gap versus the object display , and finally (5) the bar graph display versus all the other displays combined. All effects were analyzed at the  $\alpha = .05$  level.

A 5 (display type) x 2 (question type) mixed ANOVA was also performed to ascertain if there was a difference between the displays for focused and integral tasks.

The dependent measures were: percent correct strict, percent correct lenient, absolute error, and reaction time. For the percent correct strict variable an answer is considered correct only if the participant responded with the correct value. For percent correct lenient an answer is considered correct if the participant responded within the range of plus or minus one from the actual value. Absolute error is defined as the absolute value of the actual value minus the response value (  $| \text{actual value} - \text{response value} |$  ). The reaction time is measured as the speed of which the participant keyed their response to the question prompt. Each of these dependent variables were assessed for both integral and focused tasks for each type of display. These measures were obtained automatically from the computers that were used for the experiment.

The means and standard deviations for all the groups (bar, 66% gap, 33% gap, 16% gap, and object) under both integral and focused tasks are presented in Table 1.

Table 1

Means and Standard Deviations for All Conditions

		<u>BAR</u>	<u>66% GAP</u>	<u>33% GAP</u>	<u>16% GAP</u>	<u>OBJECT</u>	
<b>PctStr</b>	<u>INTEGRAL</u>	32.4 (0.107)	27.7 (0.106)	23.9 (0.118)	29.4 (0.086)	25.2 (0.094)	<b>27.7</b>
	<u>FOCUSED</u>	69.2 (0.182)	38.1 (0.130)	39.9 (0.123)	42.8 (0.098)	40.6 (0.091)	<b>46.1</b>
		<b>50.8</b>	<b>32.9</b>	<b>31.9</b>	<b>36.1</b>	<b>32.9</b>	
<b>PctLen</b>	<u>INTEGRAL</u>	72.5 (0.130)	64.2 (0.133)	65.5 (0.084)	64.6 (0.126)	61.6 (0.146)	<b>65.7</b>
	<u>FOCUSED</u>	93.3 (0.60)	69.5 (0.155)	71.0 (0.144)	76.7 (0.121)	77.4 (0.125)	<b>77.6</b>
		<b>82.9</b>	<b>66.9</b>	<b>68.3</b>	<b>70.7</b>	<b>69.5</b>	
<b>AbsErr</b>	<u>INTEGRAL</u>	1.136 (0.358)	1.396 (0.522)	1.534 (0.455)	1.356 (0.478)	1.491 (0.473)	<b>1.383</b>
	<u>FOCUSED</u>	0.616 (0.410)	1.425 (0.721)	1.461 (0.585)	1.367 (0.740)	1.269 (0.750)	<b>1.228</b>
		<b>0.876</b>	<b>1.411</b>	<b>1.498</b>	<b>1.362</b>	<b>1.380</b>	
<b>RT (ms)</b>	<u>INTEGRAL</u>	1705.455 (238.243)	1723.182 (300.789)	1931.000 (212.199)	1702.545 (277.473)	1900.545 (255.068)	<b>1792.545</b>
	<u>FOCUSED</u>	1738.727 (229.054)	1817.091 (273.506)	2073.091 (124.277)	1813.182 (273.606)	1923.545 (247.529)	<b>1873.127</b>
		<b>1722.091</b>	<b>1770.137</b>	<b>2002.046</b>	<b>1757.864</b>	<b>1912.045</b>	

Note. Numbers in bold represent marginal means  
Numbers in the parentheses represent standard deviations

For the focused tasks only two comparisons were found to be significant (refer to Figure 7) for the strict percent correct variable: (1) bar graph ( $M=69.2$ ) versus 66% gap ( $M=38.1$ ) display

$F(1,50)=32.07, p<.001$ ,

and the (2) bar graph

( $M=69.2$ ) versus all the

other conditions combined

( $M=40.4$ ),

$F(1,50)=44.10, p<.001$ .

These results are in the

direction that was

predicted by both of the

previously mentioned

hypotheses described in the introduction. The comparisons for the 66% gap ( $M=38.1$ )

versus the 33% gap ( $M=39.9$ ) display  $F(1,50)=.11, p=.741$ , the 33% gap ( $M=39.9$ )

versus 16% gap

( $M=42.8$ ) display

$F(1,50)=.28, p=.600$ ,

and finally the 16% gap

( $M=42.8$ ) versus object

( $M=40.6$ ) display

$F(1,50)=.16, p=.69$

all failed to reach

significance.

All the

comparisons for the

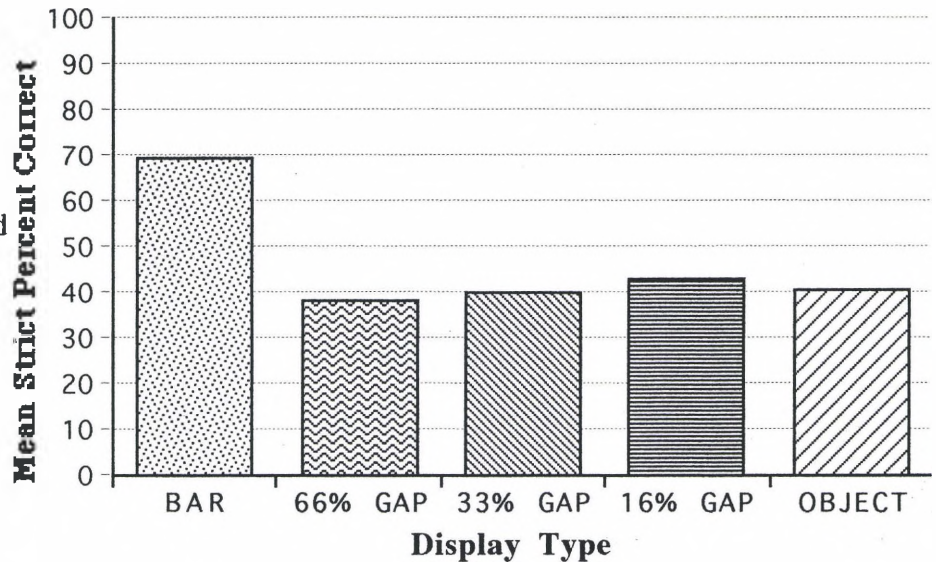


Figure 7. Mean strict percent correct for focused tasks.

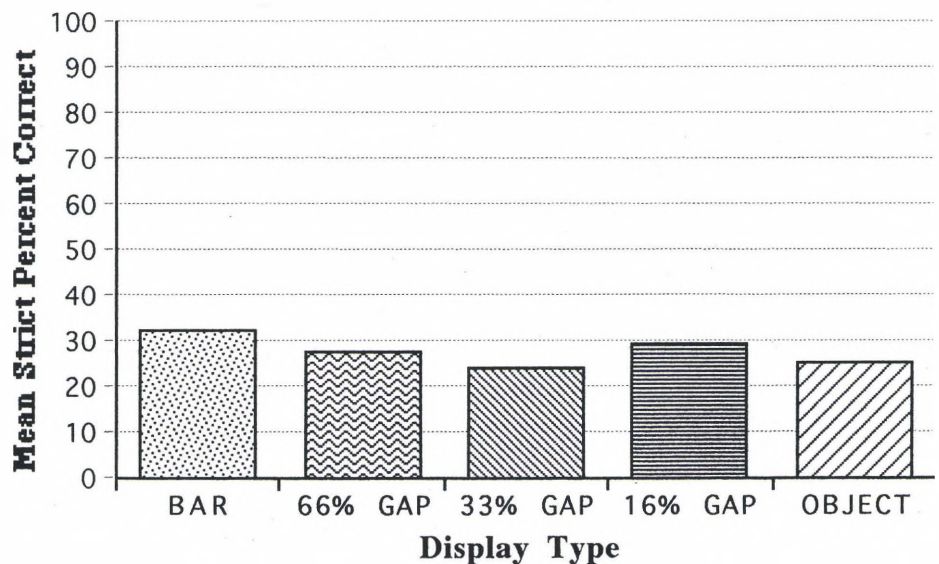


Figure 8. Mean strict percent correct for integral tasks.

strict percent correct dependent variable failed to reach significance (refer to Figure 8) for the integral task: (1) bar graph ( $M=32.4$ ) versus 66% ( $M=27.7$ ) gap display  $F(1,50)=1.17$ ,  $p=.285$ , (2) 66% ( $M=27.7$ ) versus the 33% gap ( $M=23.9$ ) display  $F(1,50)=.75$ ,  $p=.392$ , (3) the 33% ( $M=23.9$ ) versus 16% ( $M=29.4$ ) gap display  $F(1,50)=1.57$ ,  $p=.216$ , (4) the 16% gap ( $M=29.4$ ) versus the object ( $M=25.2$ ) display  $F(1,50)=.90$ ,  $p=.346$ , and finally (5) the bar graph display versus all the other conditions combined ( $M=26.6$ ),  $F(1,50)=2.87$ ,  $p=.097$ .

The 5 x 2 mixed ANOVA revealed that there was a main effect of display type ( $F(1,50)=7.56$ ,  $MS_{\text{Error}}=.02$ ,  $p<.001$ ), a main effect of question type ( $F(1,50)=104.80$ ,  $MS_{\text{Error}}=.01$ ,  $p<.001$ ), as well as an interaction ( $F(1,50)=6.82$ ,  $MS_{\text{Error}}=.01$ ,  $p<.001$ ) for the percent correct strict dependent variable (refer to Figure 9). Therefore, the participants performed more accurately with the focused task ( $M=46.1\%$ ) than with the integral task ( $M=27.7\%$ ). Also, the students performed more accurately with the bar graph condition than with any of the other display conditions. A larger difference was observed between the focused and integral tasks in the bar graph condition than in the other display conditions.

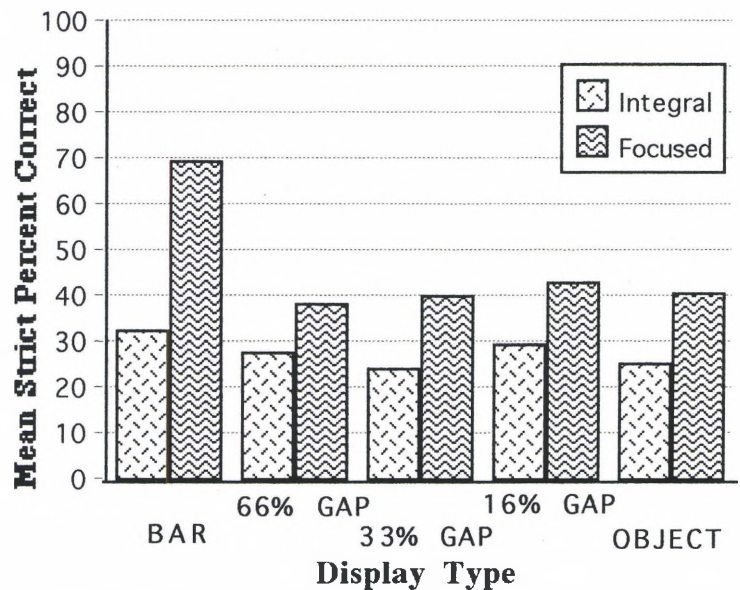


Figure 9. Mean Strict Percent Correct as a function of display and question.

A lenient percent correct measure was also used to analyze the results. Lenient was defined as having the participant's response count as correct if it was plus or minus one from the actual correct value. The results for the focused tasks (refer to Figure 10) mirror the ones from the strict percent correct criteria in that the only two comparisons that were



significant were: (1) bar

graph ( $M=93.3$ ) versus

66% gap ( $M=69.5$ )

display  $F(1,50)=19.89$ ,

$p<.001$ , and (2) the bar

graph ( $M=93.3$ ) versus

all the other displays

combined ( $M=73.7$ ),

$F(1,50)=21.72$ ,  $p<.001$ .

The comparisons for the

66% gap ( $M=69.5$ )

versus the 33% ( $M=71.0$ ) display  $F(1,50)=.07$ ,  $p=.787$ , the 33% ( $M=71.0$ ) versus the

16% gap ( $M=76.7$ ) display  $F(1,50)=1.16$ ,  $p=.287$ , and the 16% gap ( $M=76.7$ ) versus the

object ( $M=77.4$ ) display  $F(1,50)=.02$ ,  $p=.897$  all failed to reach significance.

The comparison that reached significance using the lenient percent correct

dependent measure for

the integral tasks (refer

to Figure 11) was the

bar graph display

( $M=72.5$ ) versus all the

other conditions

( $M=64.0$ ),

$F(1,50)=4.09$ ,  $p=.048$ .

This result was not

predicted by either

hypothesis offered in

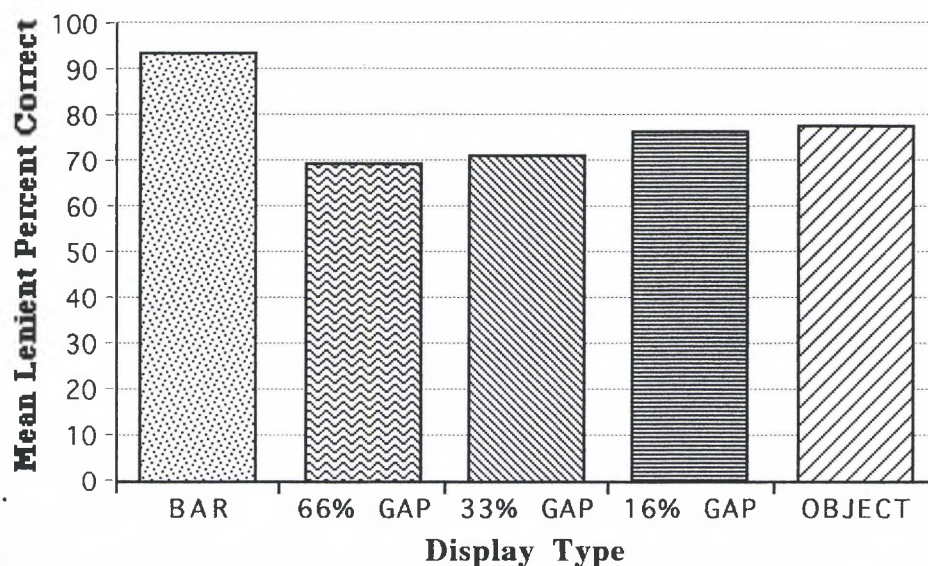


Figure 10. Mean lenient percent correct for focused tasks.

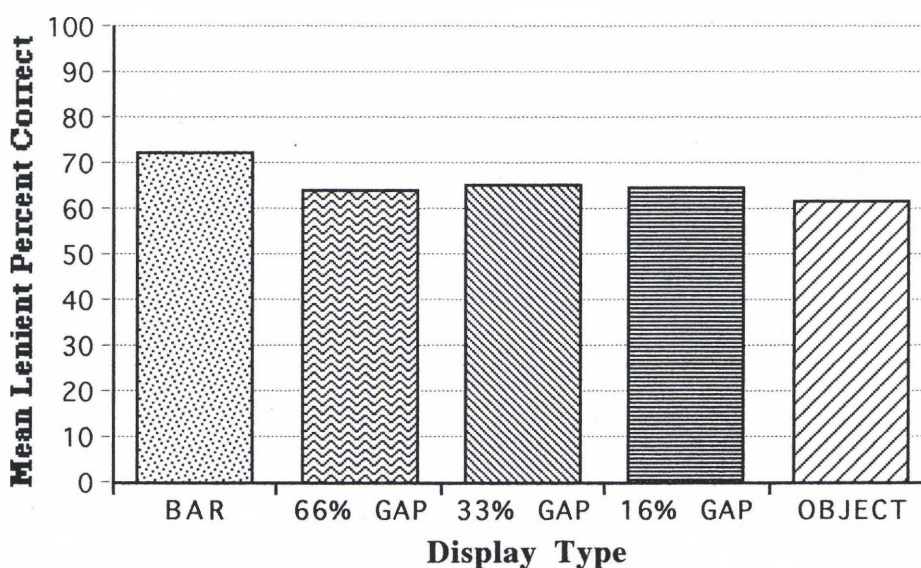


Figure 11. Mean lenient percent correct for integral tasks.

the introduction. All the rest of the comparisons failed to reach significance: (1) the bar graph ( $M=72.5$ ) versus the 66% gap ( $M=64.2$ ) display  $F(1,50)=2.42$ ,  $p=.126$ , (2) the 66% gap ( $M=64.2$ ) versus the 33% gap ( $M=65.5$ ) display  $F(1,50)=.06$ ,  $p=.806$ , (3) the 33% gap ( $M=65.5$ ) versus the 16% gap ( $M=64.6$ ) display  $F(1,50)=.03$ ,  $p=.861$ , and finally (4) the 16% gap ( $M=64.6$ ) versus the object ( $M=61.6$ ) display  $F(1,50)=.32$ ,  $p=.574$ .

The ANOVA found significant main effects for both variables as well as the interaction (refer to Figure 12): (1) main effect of display type ( $F(1,50)=4.41$ ,  $MS_{\text{Error}} = .02$ ,  $p=.006$ ), (2) main effect of

question ( $F(1,50)=42.22$ ,  $MS_{\text{Error}} =$

.01,  $p<.001$ ), and (3) the interaction

between display and question type

( $F(1,50)=2.68$ ,  $MS_{\text{Error}} = .01$ ,

$p=.042$ ). Therefore, the participants

performed more accurately with the

focused tasks ( $M=77.6\%$ ) than the

integral tasks ( $M=65.7\%$ ). The

students in the study also performed

more accurately with the bar graph

than any other display type. Finally, a

larger difference was observed between focused and integral tasks with the bar graph than any of the other display conditions.

For the focused tasks only two comparisons were found to be significant (refer to Figure 13) using the absolute error measure: (1) the bar graph ( $M=.616$ ) versus the 66% gap ( $M=1.425$ ) display  $F(1,50)=8.43$ ,  $p=.005$ , and (2) the bar graph ( $M=.616$ ) versus all the other displays combined ( $M=.1.380$ ),  $F(1,50)= 12.04$ ,  $p=.001$ . These comparisons

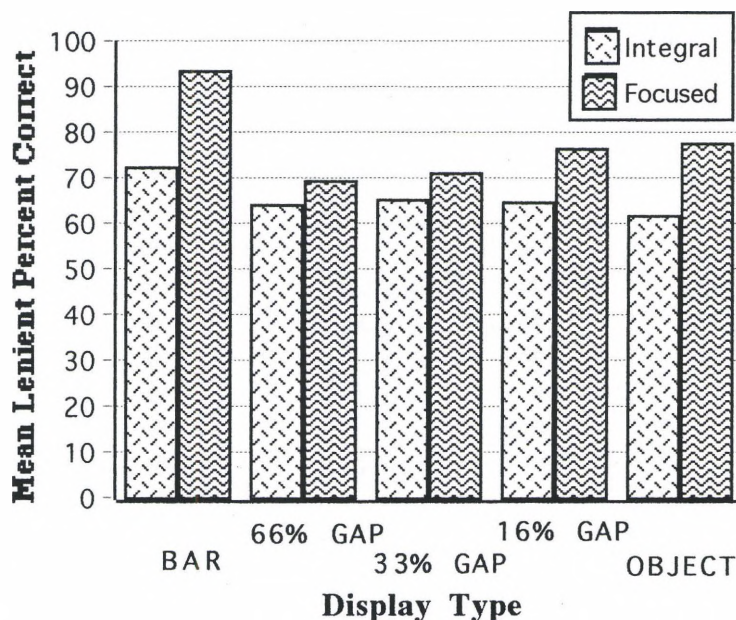


Figure 12. Mean Lenient Percent Correct as a function of display and question.



were also found to be significant in the previous dependent measures that were listed for the focused tasks, thereby lending support to the task dependency hypothesis as discussed in the introduction (p.

13). The 66% gap ( $M=1.425$ ) versus the

33% gap ( $M=1.461$ ) display  $F(1,50)=.02$ ,  $p=.900$ , the 33% gap ( $M=1.461$ ) versus the 16% gap ( $M=1.367$ ) display  $F(1,50)=.11$ ,  $p=.739$ , and finally the 16% gap ( $M=1.367$ ) versus the object ( $M=1.269$ ) display  $F(1,50)=.12$ ,  $p=.725$  all failed to reach significance.

All the comparisons for the absolute error dependent measure failed to reach significance (refer to

Figure 14) during the integral tasks.

However, the bar graph ( $M=1.136$ ) versus all the other conditions combined ( $M=1.444$ ) approached significance  $F(1,50)=3.93$ ,  $p=.053$ .

This result mirrors the result of the integral

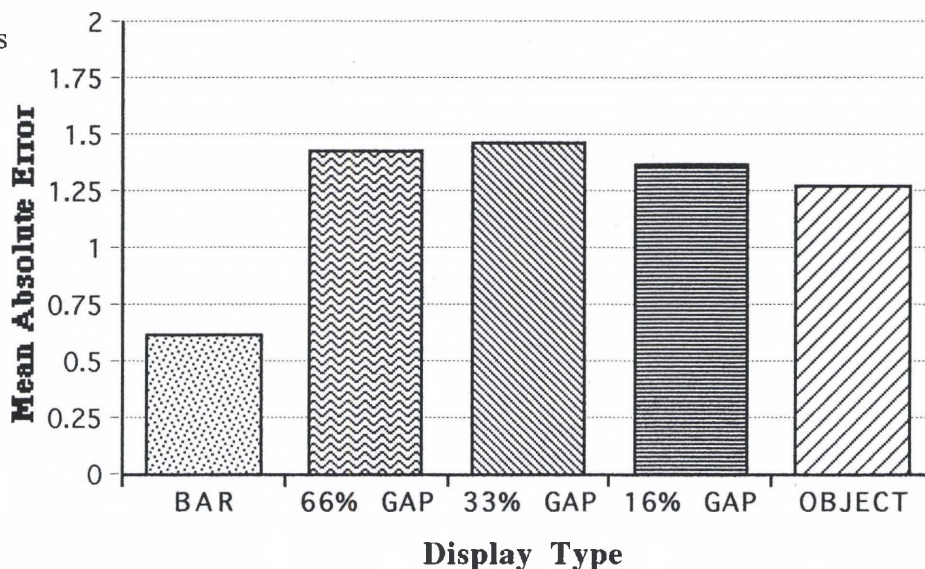


Figure 13. Mean absolute error for focused tasks.

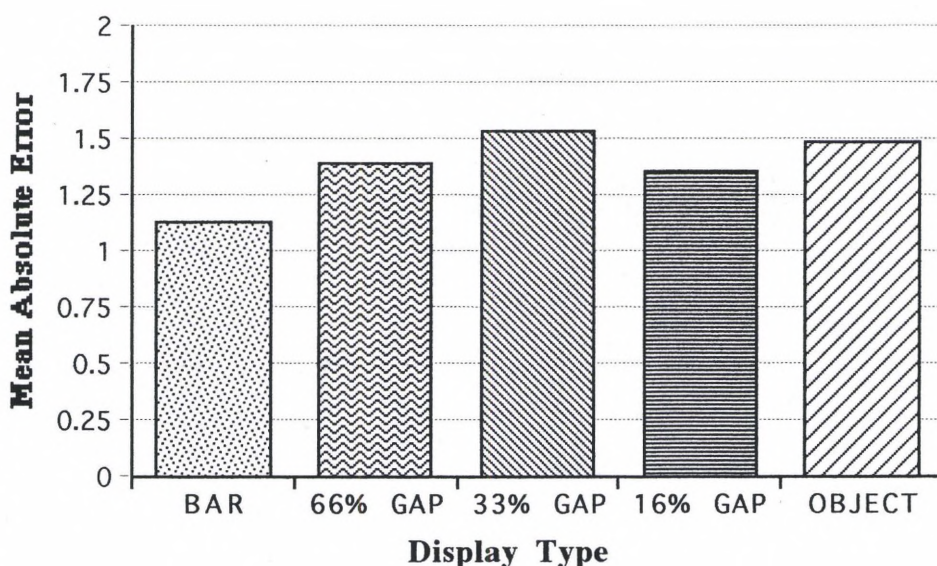


Figure 14. Mean absolute error for integral tasks.

tasks on the lenient percent correct measure, which does not support either hypothesis.

The other comparisons are as follows: (1) the bar graph ( $M=1.136$ ) versus the 66% gap ( $1.396$ ) display  $F(1,50)=1.75$ ,  $p=.192$ , (2) the 66% gap ( $M=1.396$ ) versus the 33% gap ( $1.534$ ) display  $F(1,50)=.50$ ,  $p=.485$ , (3) the 33% gap ( $M=1.534$ ) versus the 16% gap ( $M=1.356$ ) display  $F(1,50)=.82$ ,  $p=.369$ , and finally (4) the 16% gap ( $M=1.35$ ) display and the object ( $M=1.491$ ) display  $F(1,50)=.47$ ,  $p=.497$ .

For the absolute error measure, the only significant result in the ANOVA was that there was a main effect for display

type ( $F(1,50)=3.04$ , MS error = .44,  $p=.026$ ). The question variable ( $F(1,50)=3.25$ , MS error = .20,  $p=.077$ ), and the interaction ( $F(1,50)=1.40$ , MS error = .20,  $p=.248$ ) both failed to reach significance (refer to Figure 15).

Therefore, the participants performed the most accurately with the bar display than the other display conditions.

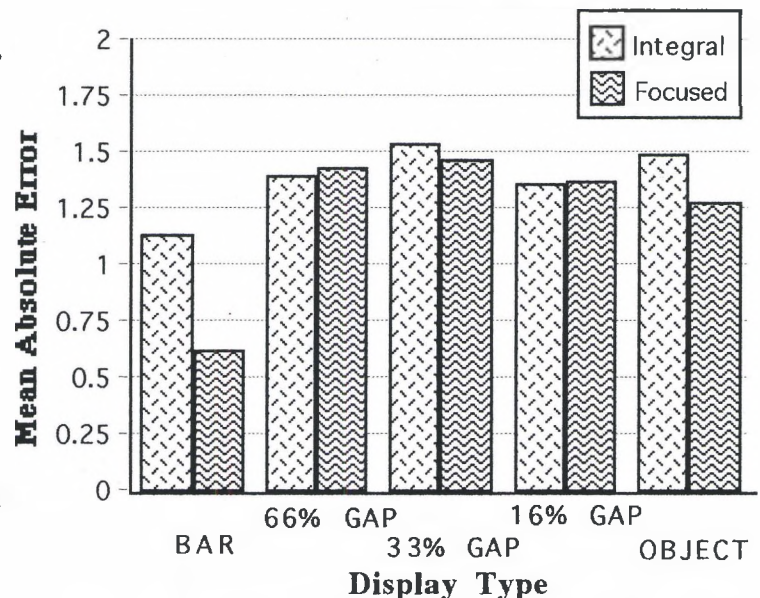


Figure 15. Mean absolute error as a function of display and question .

Three comparisons were found significant (refer to Figure 16) using the reaction time measure during the focused tasks: (1) the 33% gap ( $M=2073$  ms) versus the 16% gap ( $M=1813$  ms) display  $F(1,50)=6.66$ ,  $p=.013$ , (2) the 66% gap ( $M=1817$  ms) versus the 33% gap ( $M=2073$  ms) display  $F(1,50)=6.46$ ,  $p=.014$ , and finally (3) the bar graph ( $M=1739$  ms) versus all the other displays combined ( $M=1907$  ms),  $F(1,50)=4.45$ ,  $p=.040$ . The first two comparisons support the contention that there is a difference among the closure displays, but the difference is not in the direction that was predicted by the



author. The bar graph was expected by both hypothesis to have the fastest reaction times than any other display during focused attention tasks. The bar graph ( $M=1739$  ms) versus the 66% gap ( $M=1817$  ms) display  $F(1,50)=.61$ ,  $p=.440$ , and the 16%

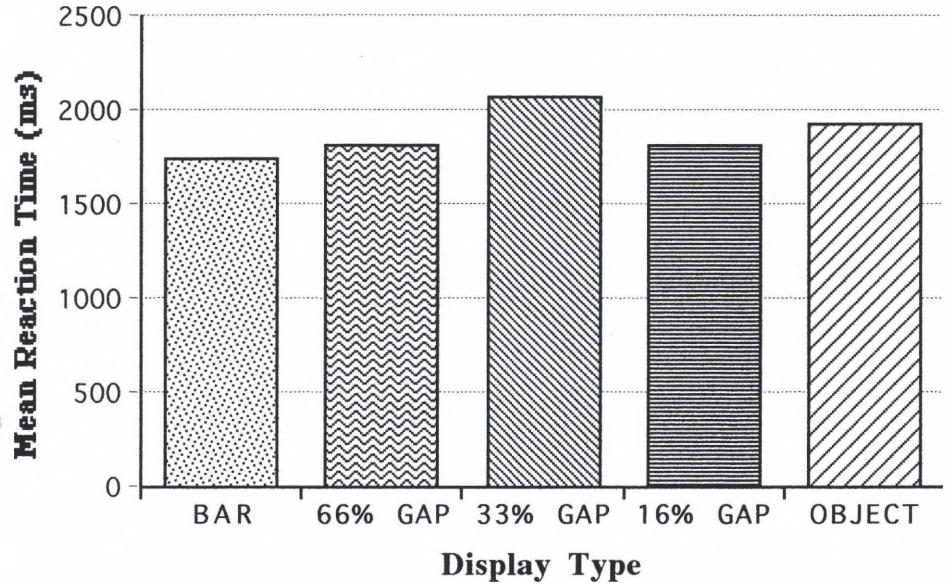


Figure 16. Mean reaction time (ms) for focused tasks.

gap ( $M=1813$  ms) versus the object ( $1924$  ms) display  $F(1,50)=1.20$ ,  $p=.278$  failed to reach significance.

The reaction time measure revealed that there was only one comparison that reached significance during the integral tasks (refer to Figure 17), which was the 33% gap ( $M=1931$  ms) versus

the 16% gap ( $M=1703$  ms) display  $F(1,50)=4.49$ ,  $p=.039$ . This result supports the prediction that there is a difference among the closure displays, and that the 16% gap display would produce faster reaction time

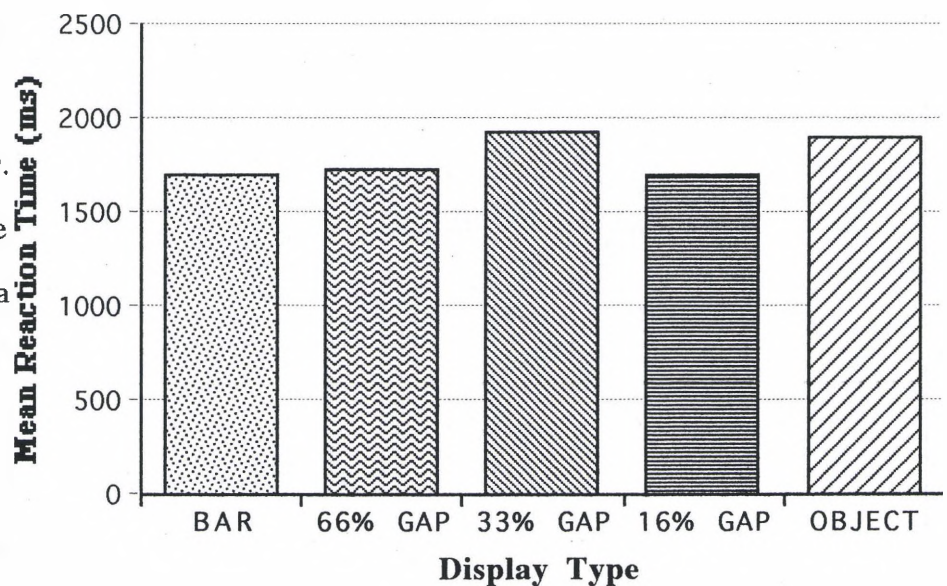


Figure 17. Mean reaction time (ms) for integral tasks.

because it is more integral than the 33% gap display. The remaining comparisons failed to reach significance: (1) bar graph ( $M=1705$  ms) versus the 66% gap ( $M=1723$  ms) display  $F(1,50)=.03$ ,  $p=.870$ , (2) the 66% gap ( $M=1723$  ms) versus the 33% gap ( $M=1931$  ms) display  $F(1,50)=3.71$ ,  $p=.060$ , (3) the 16% gap ( $M=1703$  ms) versus the object ( $M=1901$  ms) display  $F(1,50)=3.37$ ,  $p=.072$ , and finally (4) the bar graph ( $M=1705$  ms) versus all the other displays combined ( $M=1815$  ms),  $F(1,50)=1.63$ ,  $p=.208$ .

Finally, the ANOVA revealed that there was a main effect of display ( $F(1,50)=2.87$ , MS error = 108743,  $p=.032$ ), and question type ( $F(1,50)=16.22$ , MS error = 11007,  $p<.001$ ) for the reaction time measure (refer to Figure 18). However, the interaction between these variables failed to reach significance ( $F(1,50)=1.30$ , MS error = 11007,  $p=.282$ ). The participants performed more slowly with the focused tasks ( $M=1873$ ) than the integral tasks ( $M=1792$ ).

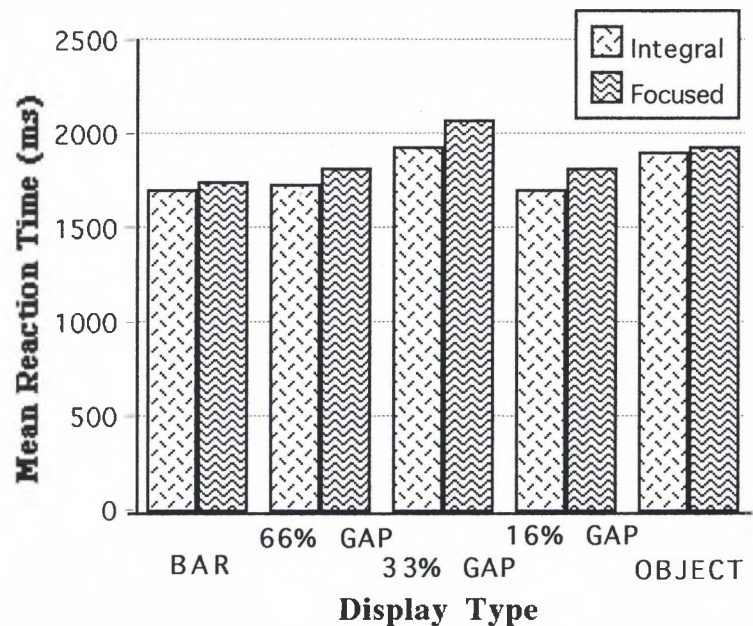


Figure 18. Mean reaction time (ms) as a function of display and question.

The following tables (Table 2 and Table 3) provide summary of the statistics for both the planned comparisons and the ANOVA.

Table 2

Statistic Summary Table for Planned Comparisons

			<u>BAR vs 66%</u>	<u>66% vs 33%</u>	<u>33% vs 16%</u>	<u>16% vs OBJECT</u>	<u>BAR vs ALL</u>
<b>PctStr</b>	<u>INTEGRAL</u>	<u>F</u>	1.170	0.750	1.570	0.900	2.870
		<u>p</u>	0.285	0.392	0.216	0.346	0.097
<b>PctLen</b>	<u>FOCUSED</u>	<u>F</u>	32.070	0.110	0.280	0.160	44.100
		<u>p</u>	0.000*	0.741	0.600	0.690	0.000*
<b>AbsErr</b>	<u>INTEGRAL</u>	<u>F</u>	2.420	0.060	0.030	0.320	4.090
		<u>p</u>	0.126	0.806	0.861	0.574	0.048*
<b>RT (ms)</b>	<u>FOCUSED</u>	<u>F</u>	19.890	0.070	1.160	0.020	21.720
		<u>p</u>	0.000*	0.787	0.287	0.897	0.000*
	<u>INTEGRAL</u>	<u>F</u>	1.750	0.500	0.820	0.470	0.393
		<u>p</u>	0.192	0.485	0.369	0.497	0.053
	<u>FOCUSED</u>	<u>F</u>	8.430	0.020	0.110	0.120	12.040
		<u>p</u>	0.005*	0.900	0.739	0.725	0.001*
	<u>INTEGRAL</u>	<u>F</u>	0.030	3.710	4.490	3.370	1.630
		<u>p</u>	0.870	0.060	0.039*	0.072	0.208
	<u>FOCUSED</u>	<u>F</u>	0.610	6.460	6.660	1.200	4.450
		<u>p</u>	0.440	0.014*	0.013*	0.278	0.040*

Note. F has 1, and 50 d.f.

\* indicates significance at alpha = .05

Table 3

Summary Table for ANOVA Statistics

	SS	DF	MS	F	p
<b>PctStr</b>					
Display	.55	4	.14	7.56	0.000*
Question	.93	1	.93	104.80	0.000*
Display x Question	.24	4	.06	6.82	0.000*
<b>PctLen</b>					
Display	.37	4	.09	4.14	0.006*
Question	.39	1	.39	42.22	0.000*
Display x Question	.10	4	.02	2.68	0.042*
<b>AbsErr</b>					
Display	5.30	4	1.33	3.04	0.026*
Question	.66	1	.66	3.25	0.077
Display x Question	1.14	4	.28	1.40	0.248
<b>RT (ms)</b>					
Display	1247896.15	4	311974.04	2.87	0.032*
Question	178569.31	1	178569.31	16.22	0.000*
Display x Question	57299.42	4	14324.85	1.30	0.282

Note. \* indicates significance at alpha = .05



## DISCUSSION

This purpose of this study was to address the unanswered question that stemmed from Schmidt (1992), which was whether the closure displays could produce a dual benefit (good focused attention and integral task performance) if the gaps of the triangle sides were manipulated. The results do not indicate that the gap manipulation had an effect on performance.

For the most part the data lend support to the view point of task dependence. According to this position, the closure and object displays should all lead to the same level of performance for the focused attention tasks, because the task of answering the question for these displays are the same. The bar graph should be superior to the rest of the displays for the focused attention tasks. This finding is also supported by the proximity of compatibility principle, because focused attention tasks are best served by low proximity displays (i.e., separable displays).

However, the results for the integral tasks were less clear-cut. Inconsistent with both sets of predictions, there was not a significant difference among any of the comparisons for strict percent correct or absolute error measures. For the lenient percent correct measure, the only comparison found significant was between the bar graph and the rest of the displays combined. This result was surprising because it was not supported by either the proximity of compatibility principle or the task dependent hypothesis as discussed in the introduction. The proximity of compatibility principle states that high proximity displays lead to better performance on integral type tasks, which was not found to be the case. The task dependency principle implied that all the triangle displays would lead to better performance than the bar graph display during integral tasks, which also was not supported by the present data.

The reaction time results support both sets of predictions that the bar graph would lead to better performance than the other displays during focused attention tasks.

However, there were two other planned comparisons that were found significant: (1) the 66% gap versus the 33% gap, and (2) the 33% gap, and the 16% gap display. This suggests that there is a difference between the closure displays as predicted. It was predicted that the 66% gap display would have a faster reaction time than the 33% gap display, due to the fact that the 66% gap display was the most separable of the closure displays. This prediction was supported by the data. However, the author also predicted that the 33% gap display would have faster reaction times than the 16% gap because the 16% gap display was most like the object display. This contention was not supported by the data that suggest that the 16% gap display had faster reaction times than the 33% gap display during focused attention tasks.

The only comparison for the reaction time measure that was significant during the integral task was the 33% versus 16% gap displays. This result supports the author's prediction that there would be a difference between the closure displays, and that the 16% gap display would allow for faster reaction times during integral tasks. The reason for this prediction is that the 16% gap display is the most integral of the three closure displays, and therefore should have a faster reaction time on integral tasks than the 33% gap display.

#### Interpreting Results at Face Value

If the data from this study are taken at face value there are some important implications that need to be addressed regarding the principles of proximity of compatibility and emergent features; both were discussed in the introduction. For the most part the data do not support the proximity of compatibility principle, because the bar graph display was found to do as well as or better than the other displays during both focused attention and integral type tasks.

As discussed in the introduction, emergent features are known to be linked to good performance when the task requires integration of information. Based on previous research, it was predicted that the object display would do well on the integral tasks;

however this prediction was not supported. As previously noted, the strict percent correct and absolute error measures did not show any significant difference between any of the five displays. The lenient percent correct measure revealed that the bar graph versus all the other displays combined was the only significant comparison, which further does not support the principle of emergent features. Finally, the reaction time measure only had one significant comparison which was between two of the closure displays. One would have thought that the object display (having the most salient emergent feature) would have lead to faster reaction times than the other four displays. Therefore, the principles of compatibility and emergent features are not supported by the data obtained from this study.

#### Present Study versus Schmidt (1992)

One of the main purposes of this experiment was to take the results from Schmidt (1992) one step further by adding the two additional closure display conditions. Therefore examining the specific similarities and differences between the results of the two studies may be beneficial.

There are a few similarities that are worth mentioning. One such similarity has to do with the error measures results for both experiments. Specifically, the means of the error measures for the focused attention tasks seem to be going in the same direction as the means in Schmidt (1992). Both studies found that the direction of the means showed that the bar graph led to the least amount of errors, followed by the closure and object displays. Also, both studies did not show a significant difference of performance between any of the displays during the integral task questions.

Neither of the two studies fully support the dual benefit hypothesis for the closure display. Both of the studies had the participants answer three times as many focused attention questions as integral questions. The fact that the odds were not stacked in favor of finding this benefit may have contributed to the results found in both studies. In other words, a possible reason for the results not supporting the dual benefit hypothesis may be

due to the fact that integral questions were only presented a quarter of the time; the remaining percentage consisted of separable questions (heart rate, blood pressure, or temperature). A more detailed description of this phenomenon is described in the following section.

One major difference between these studies was that the current study found a substantial difference in the percentage correct results. Specifically, the percentage correct data for the current study was found to be substantially higher for all the common displays (used by both Schmidt (1992) and the current experiment) during both integral and focused attention tasks as compared to Schmidt's. Although both sets of participants were from the same population (University of Dayton undergraduates), it is quite possible that the population has changed since 1992. In fact, this is one of the reasons why the bar graph and object displays were included as control conditions for this study. This explanation is further supported by the fact that very different results were obtained for both studies with regards to finding a dual benefit. Although the displays and questions were the same, the results and their explanations were very different.

Another important difference between the two studies is that the present study found that all the comparisons of the displays failed to reach significance for the strict percent correct variable on the integral tasks. However, this is the measure where Schmidt (1992) found partial support for dual benefit of the closure display. He found that the closure display led to a higher percentage correct than the object, but equal to the bar graph. Although Schmidt found that the bar graph had the highest accuracy on focused attention tasks as in the present experiment, he also found that there was a significant difference in performance between the closure and object displays. However, the present study does not support this difference between the closure and object displays. What these differences finally allude to is that the bar graph display, for the most part, led to better or equivalent results to the other displays for both type of tasks. Therefore, the results of this study do



not support the dual benefit hypothesis of the closure display.

### Possible Explanations for Results

There are several possibilities for why the bar graph did better than expected. The most compelling reason is that the odds were in favor of the bar graph doing better. This is due to the fact that three out of the four questions (heart rate, temperature, blood pressure, and syndrome) that were asked consisted of focused attention questions. Therefore, the participants were only asked to integrate information 25% of the time; allowing for greater amounts of practice for the focused attention tasks. Elvers, Adapathya, Klauer, Kancler, and Dolan (1993) found that object displays did better on integral tasks when the probability of having to integrate information increased. A potential reason why the results of this study go against much of the typical object display data is that much of the previous research has used a higher percentage of integral tasks, thus stacking the odds in their favor.

Another possible reason for the unexpected result of the triangle displays not doing significantly better than the bar graph display during the integral tasks may be due to the vividness of the emergent feature. It is possible that the emergent feature may not have been vivid enough to effectively estimate the syndrome value. Maybe if the triangles were formed more similar to the subjective contour shown in Figure 2 (Laurie et al. 1994), the participants may have had an easier time estimating the area of the triangles. This may explain why the bar graph had a significantly higher lenient percentage correct than the triangle displays, and why the absolute error and strict percent correct measures all failed to reach significance for the integral tasks. Schmidt's (1992) results also lend credence to this hypothesis because the percent correct measure for the object and closure displays were actually higher during the focused attention tasks than for the integral tasks.

There is another viewpoint that may explain the present results with regard to emergent features. There are numerous emergent features in the triangle displays, rather

than just area. The overall shape, the angles of the vertices, as well as area may all be considered emergent features in the triangle displays. Perhaps a reason why the bar graph did better than expected on the integral task may be due to the fact that there were many emergent features that were present in the display that had to be ignored due to their meaninglessness to the task. Thus, the bar graph condition actually ended up being simpler because there were no complex equations (as in the triangle displays) and no emergent features that had to be ignored.

Proponents of this hypothesis might argue that the participants did not follow the directions for performing the integration task for the bar graph display (mentally rotate bars to form a triangle). It is possible that the participants used a technique similar to the one described in Gillan (1995). Gillan had participants perform visual arithmetic to determine the mean of a set of data. In other words, the participants in this experiment taught themselves how to look at the lengths of the bars and determine an average length. From this average length they formed their own criterion that came close to or matched the one given by the computer. Elvers and Dolan (1995) found increased integration performance when they added an extra bar to the bar graph display. This additional bar indicated the area of the imagined triangle, which is essentially what the participants in the present study were determining by informally using the visual arithmetic method.

A simulation was conducted to test this hypothesis. It was found that the area of the imagined triangle correlated significantly ( $r=.96$ ) with the average length of the bars. This supports the hypothesis that the participants were performing a technique similar to the one described by Gillan. Another simulation study was conducted to determine whether there is a correlation between the amount of variability between the bars on the bar graph display and reaction time. Proponents of this hypothesis would predict quicker reaction times when there was little variability between the heights of the bars, due to it being easier to determine the average length. However, this was not found to be the case ( $r=-0.078$ ).

Therefore, this issue is still unresolved and should be considered in future research.

Another possible explanation for the bar graph doing well may be due to the fact that the participants were more familiar with them, as opposed to the other displays used in this experiment. The fact that the bar graph had the highest strict and lenient percentage correct values for both focused and integral tasks supports this contention. The data also revealed that the bar graph had the smallest error rate for the focused attention tasks. Although not statistically significant, the same general trend was found for the integral tasks. If we combine this with the fact that there were three times as many focused tasks as there were integral tasks, it can explain why the bar graph did so well on both types of tasks. Also it has been shown that assessing the area of a triangle is significantly harder than assessing the length of a bar on a bar graph display (Cleveland, 1990). In fact, the study suggests the only things harder than determining the area of a figure is assessing volume or color saturation.

A possible explanation for the reaction time data being faster for the integral versus the focused attention tasks is that the different tasks may have different processing requirements. In other words, it may take longer to find the specific part of the display for the focused attention task, whereas it is faster to process the display as a whole for the integral task.

#### Implications for Further Research

Although this study's results did not turn out exactly as planned, it brings up several more questions regarding object displays that should be further investigated. First off, it would be interesting to perform this experiment again with the integral and focused attention probabilities reversed. This means that we would have the focused attention task question occur only 25% of the time, and have the remaining 75% of the questions be of the integral type. If a study like this were conducted, and the results were the same it would have more concrete implications for object display research.

Another factor that should be investigated is practice. It would be interesting to see how the results came out if everyone had to obtain a certain percentage of integral and separable questions correct before moving on to the experimental trials. It is through this procedure that a baseline could be established across all the participants regarding their proficiency in answering both types of questions.

Another interesting follow-up experiment would be to see if manipulating how the closure and object display triangles were formed had an effect on the results. In other words we could manipulate if the closure and object display triangles were formed like the square displayed in Figure 2 (Laurie et al. 1994), or if the triangles were formed as they were for this present study. This could determine whether the subjective contour was vivid enough to accurately make syndrome estimations on the integral type tasks.

All the possible experiments mentioned above address one specific issue in trying to determine why the results turned out as they did. However, there is one critical experiment that would address the two viewpoints that were presented in this thesis. To review, one view point had to do with the task probabilities assigned to the question types. The other view is that there were just too many emergent features that were contained in the triangle displays, and that is why the bar graph did better than expected on the integral tasks. The critical experiment would be to manipulate both task probability (integral and focused) and the number of emergent features on the object displays. The emergent features could be manipulated by using shapes that have fewer emergent features (ie., rectangle) versus shapes that have more emergent features (ie., the triangle used in the present experiment). The results of this experiment would attempt to clear the issue of why the results of this study turned out the way they did.

### Summary

This study attempted to answer Schmidt's (1992) question of whether manipulating the length of the triangle sides on a closure display would produce a dual effect on focused

attention and integral type tasks. The results of this study did not support the partial benefit of the closure display that was found in Schmidt (1992). Specifically, the bar graph was shown to lead to equal or better performance on the dependent measures than the other triangle displays.

However, this result may be due to the fact that there were three times more focused attention tasks than integral tasks. The fact that the participants only had a quarter of the practice for the integral tasks may have worked against finding a result supporting the dual benefit hypothesis. The results could also be due to the number of irrelevant emergent features contained in the triangle displays versus the bar graph. A critical experiment is proposed to examine the reason behind the results of the present study.

APPENDIX A

PARTICIPANT INSTRUCTIONS AND DEBRIEFINGS

Adapted from Schmidt (1992)

## PARTICIPANT INSTRUCTIONS: BAR GRAPH

SECTION 1: In this experiment we will ask you to imagine yourself as a medical technician monitoring a patient who is undergoing surgery. You will be presented with the patient's medical information shown in a bar graph format. A question regarding the numerical value of the information will appear below the bar graph. You are to respond to the question by typing the single key that corresponds to your answer. Do you have any questions before we proceed?

I would like to make sure that you understand you have the right to leave this, or any psychological experiment, at any time, without incurring any penalties whatsoever. Do you understand this? Please, read, sign and date the information on the consent form.

SECTION 2: First, I would like to show you what the bar graph looks like. The bars represent the values for the patient's 3 variables of HEART RATE, BLOOD PRESSURE, and TEMPERATURE. HEART RATE is always at the left end, BLOOD PRESSURE in the middle, and TEMPERATURE at the right end. These words will not appear on the screen, so you will need to remember what each bar represents. The higher the top of the bar, the larger the value of that variable. There are a maximum of 9 positions the bar can be in, ranging from the values 1 through 9. From one trial to the next, any bar can be in any one of the 9 positions.

You will have 4 different tasks in this experiment. Three of these tasks involve estimating the particular value of one of the 3 variables of Heart rate, Blood pressure, and Temperature. The variable you are to estimate will be indicated by the presence of one of the words "HEART," "PRESSURE," or "TEMPERATURE" below the graph. The other task involves estimating the likelihood of the patient contracting SCHMELVERS' SYNDROME during the surgery. This estimation involves you piecing together the information of Heart rate, Blood pressure, and Temperature in a special way. This task will be indicated by the presence of the prompt "SYNDROME" under the bar graph.



When you see the word “SYNDROME,” we would like you to imagine the bars connected at a common point, with the ends of the bars connected by lines forming a triangle. You are only to do this when you see the word SYNDROME. The likelihood of SCHMELVERS’ SYNDROME is represented by the area of this imagined triangle. The computer combines the values of the 3 variables into a formula to arrive at the correct SYNDROME likelihood. The area of this imagined triangle will GET LARGER as the values of the formula get larger. The SYNDROME likelihood (area) is a perceived and relative one, not a simple mathematical one. The triangle area will be assessed on a relative but arbitrary scale of 1 to 9. The specific numbers 1 through 9 have no numeric value. In other words, the numbers act as labels for the imagined triangle areas. Bar graphs with larger bars should be imagined as forming larger triangles. THE LARGER the imagined triangle the larger the number you should enter for a SYNDROME value. Do you have any questions?

You now will do 2 blocks of 48. The computer will randomly select one of the four questions for each trial. When the bar graph and question appear, you are to respond by entering the appropriate digit using the numeric key pad on the right of the keyboard. Then, the computer will tell you if you were correct or not and display the correct value and your reaction time. If you do not respond within 3.5 seconds, the computer will display the appropriate value and move on to the next trial. The display with the question, your response, and the feedback make up one trial. I will stay in the room with you during these trials. Do you have any questions? Please begin.

SECTION 3: This concludes the practice session. Do you have any questions? For this part of the experiment we ask that you please push your chair up against the wall behind you. You may place the keyboard in your lap. Sitting this way will ensure that the displays are perceived at a constant size for each participant in this study. Please feel free to squirm and fidget as needed to feel comfortable, but we do ask that you try to refrain from

slouching or leaning forward. There will be 4 blocks of 48 trials each in this part of the experiment. At the end of each block of trials, you will be given the opportunity to take a break. There is a minimum break duration programmed in the computer, but you may take a longer break if you wish.

Please keep your fingers on the keypad, for this will speed up how quickly you respond. Please respond as accurately as you can. Within that constraint please respond as quickly as you can. Remember, your patient is counting on you being both quick and accurate. I will be sitting outside the room. If anything goes wrong, if you have any questions, or if you decide not to continue with the experiment, please open the door and I will assist you. When the computer indicates the experiment is over please let me know. At that time I will briefly explain to you what the experiment was about. Do you have any questions?

## PARTICIPANT INSTRUCTIONS: OBJECT DISPLAY

SECTION 1: In this experiment we will ask you to imagine yourself as a medical technician monitoring a patient who is undergoing surgery. You will be presented with the patient's medical information using a triangle format. A question regarding the numerical value of the information will appear below the triangle. You are to respond to the question by typing the single key that corresponds to your answer. Do you have any questions before we proceed?

I would like to make sure that you understand you have the right to leave this, or any psychological experiment, at any time, without incurring any penalties whatsoever. Do you understand this? Please, read, sign and date the information on the consent form.

SECTION 2: First, I would like to show you what the triangle looks like. The vertices (endpoints) of the triangle represent the values for the patient's 3 variables of HEART RATE, BLOOD PRESSURE, and TEMPERATURE. HEART RATE is always at the top, BLOOD PRESSURE at the left bottom, and TEMPERATURE at the right bottom. These words will not appear on the screen, so you will have to remember what each vertex represents. The center point of the figure represents a value of zero. The farther away the vertex is from the center point, the larger the value it represents. There are a maximum of 9 positions a vertex can be in, ranging from the values 1 through 9. From one trial to the next, any vertex can be in any one of the 9 positions from the center point.

You will have 4 different tasks in this experiment. Three of these tasks involve estimating the particular value of one of the 3 variables of Heart rate, Blood pressure, and Temperature. The variable you are to estimate will be indicated by the presence of one of the words "HEART," "PRESSURE," or "TEMPERATURE" below the graph. The other task involves estimating the likelihood of the patient contracting SCHMELVERS' SYNDROME during the surgery. This estimation involves you piecing together the information of Heart rate, Blood pressure, and Temperature in a special way. This task

will be indicated by the presence of the prompt “SYNDROME” under the triangle.

During a SYNDROME task, the computer combines the values of the three variables into a formula to arrive at the correct syndrome likelihood. The area of this triangle will GET LARGER as the values for the formula get larger. The SYNDROME likelihood (area) is a perceived and relative one, not a simple mathematical one. The triangle area will be assessed on a relative but arbitrary scale of 1 to 9. The specific numbers 1 through 9 have no numeric value. In other words, the numbers act as labels for the areas. The LARGER the triangle, the larger the number you should enter for a SYNDROME value. Do you have any questions?

You now will do 2 blocks of 48. The computer will randomly select one of the four questions for each trial. When the figure and question appear, you are to respond by entering the appropriate digit using the numeric key pad on the right of the keyboard. Then, the computer will tell you if you were correct or not and display the correct value and your reaction time. If you do not respond within 3.5 seconds, the computer will display the appropriate value and move on to the next trial. The display with the question, your response, and the feedback make up one trial. I will stay in the room with you during these trials. Do you have any questions? Please begin.

SECTION 3: This concludes the practice session. Do you have any questions? For this part of the experiment we ask that you please push your chair up against the wall behind you. You may place the keyboard in your lap. Sitting this way will ensure that the displays are perceived at a constant size for each participant in this study. Please feel free to squirm and fidget as needed to feel comfortable, but we do ask that you try to refrain from slouching or leaning forward. There will be 4 blocks of 48 trials each in this part of the experiment. At the end of each block of trials, you will be given the opportunity to take a break. There is a minimum break duration programmed in the computer, but you may take a longer break if you wish.

Please keep your fingers on the keypad, for this will speed up how quickly you respond. Please respond as accurately as you can. Within that constraint please respond as quickly as you can. Remember, your patient is counting on you being both quick and accurate. I will be sitting outside the room. If anything goes wrong, if you have any questions, or if you decide not to continue with the experiment, please open the door and I will assist you. When the computer indicates the experiment is over please let me know. At that time I will briefly explain to you what the experiment was about. Do you have any questions?

PARTICIPANT INSTRUCTIONS: CLOSURE TRIANGLES (16%, 33% and 66%)

SECTION 1: In this experiment we will ask you to imagine yourself as a medical technician monitoring a patient who is undergoing surgery. You will be presented with the patient's medical information shown in a pictorial format. A question regarding the numerical value of the information will appear below the display. You are to respond to the question by typing the single key that corresponds to your answer. Do you have any questions before we proceed?

I would like to make sure that you understand you have the right to leave this, or any psychological experiment, at any time, without incurring any penalties whatsoever. Do you understand this? Please, read, sign and date the information on the consent form.

SECTION 2: First, I would like to show you what the display looks like. This is a figure formed by a perceptual law. What does it look like to you? IF PARTICIPANT DOES NOT SEE A TRIANGLE, TELL THEM THAT WE INTEND IT TO LOOK LIKE A TRIANGLE, WHICH IS WHAT MOST PEOPLE SEE. The vertices (endpoints) of the "triangle" represent the values for the patient's 3 variables of HEART RATE, BLOOD PRESSURE, and TEMPERATURE. HEART RATE is always at the top, BLOOD PRESSURE at the left bottom, and TEMPERATURE at the right bottom. These words will not appear on the screen, so you will have to remember what each vertex represents. The center point of the figure represents a value of zero. The farther away the vertex is from the center point, the larger the value it represents. There are a maximum of 9 positions a vertex can be in, ranging from the values 1 through 9. From one trial to the next, any vertex can be in any one of the 9 positions from the center point.

You will have 4 different tasks in this experiment. Three of these tasks involve estimating the particular value of one of the 3 variables of Heart rate, Blood pressure, and Temperature. The variable you are to estimate will be indicated by the presence of one of the words "HEART," "PRESSURE," or "TEMPERATURE" below the graph. The other



task involves estimating the likelihood of the patient contracting SCHMELVERS' SYNDROME during the surgery. This estimation involves you piecing together the information of Heart rate, Blood pressure, and Temperature in a special way. This task will be indicated by the presence of the prompt "SYNDROME" under the triangle.

During a SYNDROME task, the computer combines the values of the three variables into a formula to arrive at the correct syndrome likelihood. The area of this triangle will GET LARGER as the values for the formula get larger. The SYNDROME likelihood (area) is a perceived and relative one, not a simple mathematical one. The triangle area will be assessed on a relative but arbitrary scale of 1 to 9. The specific numbers 1 through 9 have no numeric value. In other words, the numbers act as labels for the areas. The LARGER the triangle, the larger the number you should enter for a SYNDROME value. Do you have any questions?

You now will do 2 blocks of 48 trials. The computer will randomly select one of the four questions for each trial. When the figure and question appear, you are to respond by entering the appropriate digit using the numeric key pad on the right of the keyboard. Then, the computer will tell you if you were correct or not and display the correct value and your reaction time. If you do not respond within 3.5 seconds, the computer will display the appropriate value and move on to the next trial. The display with the question, your response, and the feedback make up one trial. I will stay in the room with you during these trials. Do you have any questions? Please begin.

SECTION 3: This concludes the practice session. Do you have any questions? For this part of the experiment we ask that you please push your chair up against the wall behind you. You may place the keyboard in your lap. Sitting this way will ensure that the displays are perceived at a constant size for each participant in this study. Please feel free to squirm and fidget as needed to feel comfortable, but we do ask that you try to refrain from slouching or leaning forward. There will be 4 blocks of 48 trials each in this part of the

experiment. At the end of each block of trials, you will be given the opportunity to take a break. There is a minimum break duration programmed in the computer, but you may take a longer break if you wish.

Please keep your fingers on the keypad, for this will speed up how quickly you respond. Please respond as accurately as you can. Within that constraint please respond as quickly as you can. Remember, your patient is counting on you being both quick and accurate. I will be sitting outside the room. If anything goes wrong, if you have any questions, or if you decide not to continue with the experiment, please open the door and I will assist you. When the computer indicates the experiment is over please let me know. At that time I will briefly explain to you what the experiment was about. Do you have any questions?

### DEBRIEFING: BAR GRAPH DISPLAY

This study investigated how information should be visually presented to humans when they either have to take in different pieces of information at once (integrate) them or concentrate on one piece of information at a time (focused attention). Research studying the use of geometric objects to convey information for these tasks is known as “object display” research. A major result of this research has been that objects have “emergent features.” An emergent feature of a set of stimuli is what allows the set to be perceived as a whole unit. For example, one does not recognize a triangle by seeing the segments making up the legs, but rather by its more complex features (such as its area).

Enclosed objects such as triangle promote good performance when source of information must be integrated, such as estimating the likelihood of the existence of Schmelver’s Syndrome. However, the object display does not promote good performance when specific values must be identified, such as estimating the value of a single syndrome variable. Also, bar graphs have been shown to promote good performance on focused attention tasks, but not on integration tasks.

In our experiment, some students used a triangle formed by a perceptual law, while others used an enclosed triangle. You, however, were a member of the group that used a bar graph. We expect that your display type will promote good performance on focused attention tasks, but poor performance on integration tasks, so do not feel bad if you had difficulty with the SYNDROME estimations. This condition was used in the experiment to replicate findings of a previous experiment to show that bar graphs are typically not a useful way to help people integrate information. We told students to integrate the bars by imagining them forming a triangle, to show that even with special instructions, bar graphs do not help integrate information.

The format that we expect to promote the best performance for both tasks out of all formats is the triangle formed by a perceptual law that other participants used in our study.

The law is known as the Gestalt Law of Closure. This law states that incomplete contours are “filled in” by humans perceptually in order to see the space as an object (Koffka, 1935). Therefore, this display should promote good performance when one must integrate information. But, when one focuses on just one part of a closure figure, the space is no longer seen as an entire object -- one merely sees the separate piece focused upon (Kaniza, 1976). In this case then, the closure figure should promote good performance when one must focus attention on one piece of information. Therefore, we believe the closure display will provide the best overall performance on all tasks. However, previous research has obtained mixed results on this issue. That is one of the reasons why we had three different closure groups, which manipulated the amount of space between the triangle vertices. We predict that the larger the space between the triangle vertices, the better the focused attention performance, because it will be easier to focus on the individual variables. We also predicted that having smaller space between vertices will promote better integral performance, because it will be easier to see the object and integrate the pieces of information. Ultimately, we are trying to confirm that these closure displays are superior to other types of displays, as well as to determine how much space is required for the participant to have the highest possible performance on both tasks.

If you would like to read more about this sort of research, here are a few references:

- Carswell, C.M., & Wickens, C.D. (1987). Information integration and the object display: An integration of task demands and display superiority. *Ergonomics*, 30, 511-527.
- Kaniza, G. (1976). Subjective contours. In J.M. Wolfe (Ed.). *The Mind's Eye* (pp. 82-86). New York: W.H. Freeman and Company.
- Wickens, C.D., & Andre, A. (1990). Proximity compatibility and information display: Effects of color, space, and objectness on information integration. *Human Factors*, 32, 61-77.

### DEBRIEFING: OBJECT DISPLAY

This study investigated how information should be visually presented to humans when they either have to take in different pieces of information at once (integrate) them or concentrate on one piece of information at a time (focused attention). Research studying the use of geometric objects to convey information for these tasks is known as “object display” research. A major result of this research has been that objects have “emergent features.” An emergent feature of a set of stimuli is what allows the set to be perceived as a whole unit. For example, one does not recognize a triangle by seeing the segments making up the legs, but rather by its more complex features (such as its area).

Enclosed objects such as a triangle promote good performance when sources of information must be integrated, such as estimating the likelihood of the existence of Schmelver’s Syndrome. However, the object display does not promote good performance when specific values must be identified, such as estimating the value of a single syndrome variable. Also, bar graphs have been shown to promote good performance on focused attention tasks, but not on integration tasks.

In our experiment, some students used a triangle formed by a perceptual law, while others used a bar graph format. You however, were a member of the group that used an enclosed triangle. We expect that your display type will promote good performance on integration tasks, but poor performance on focused attention tasks.

The format that we expect to promote the best performance for both tasks out of all formats is the triangle formed by a perceptual law that other participants used in our study. The law is known as the Gestalt Law of Closure. This law states that incomplete contours are “filled in” by humans perceptually in order to see the space as an object (Koffka, 1935). Therefore, this display should promote good performance when one must integrate information. But, when one focuses on just one part of a closure figure, the space is no longer seen as an entire object -- one merely sees the separate piece focused upon (Kaniza,



1976). In this case then, the closure figure should promote good performance when one must focus attention on one piece of information. Therefore, we believe the closure display will provide the best overall performance on all tasks. However, previous research has obtained mixed results on this issue. That is one of the reasons why we had three different closure groups, which manipulated the amount of space between the triangle vertices. We predict that the larger the space between the triangle vertices, the better the focused attention performance, because it will be easier to focus on the individual variables. We also predicted that having smaller space between vertices will promote better integral performance, because it will be easier to see the object and integrate the pieces of information. Ultimately, we are trying to confirm that these closure displays are superior to other types of displays, as well as to determine how much space is required for the participant to have the highest possible performance on both tasks.

If you would like to read more about this sort of research, here are a few references:

- Carswell, C.M., & Wickens, C.D. (1987). Information integration and the object display: An integration of task demands and display superiority. *Ergonomics*, 30, 511-527.
- Kaniza, G. (1976). Subjective contours. In J.M. Wolfe (Ed.). *The Mind's Eye* (pp. 82-86). New York: W.H. Freeman and Company.
- Wickens, C.D., & Andre, A. (1990). Proximity compatibility and information display: Effects of color, space, and objectness on information integration. *Human Factors*, 32, 61-77.

### DEBRIEFING: 16% CLOSURE TRIANGLE DISPLAY

This study investigated how information should be visually presented to humans when they either have to take in different pieces of information at once (integrate) them or concentrate on one piece of information at a time (focused attention). Research studying the use of geometric objects to convey information for these tasks is known as “object display” research. A major result of this research has been that objects have “emergent features.” An emergent feature of a set of stimuli is what allows the set to be perceived as a whole unit. For example, one does not recognize a triangle by seeing the segments making up the legs, but rather by its more complex features (such as its area).

Enclosed objects such as a triangle promote good performance when sources of information must be integrated, such as estimating the likelihood of the existence of Schmelver’s Syndrome. However, the object display does not promote good performance when specific values must be identified, such as estimating the value of a single syndrome variable. Also, bar graphs have been shown to promote good performance on focused attention tasks, but not on integration tasks.

In our experiment, some students used a type of closure triangle, enclosed triangle, or a bar graph format. You were a member in what we call a “16% closure triangle” group. This means that there were very small gaps in the sides of your triangle. We predicted that having smaller space between vertices will promote better integral performance, because it will be easier to see the object and integrate the pieces of information.

The law is known as the Gestalt Law of Closure. This law states that incomplete contours are “filled in” by humans perceptually in order to see the space as an object (Koffka, 1935). Therefore, this display should promote good performance when one must integrate information. But, when one focuses on just one part of a closure figure, the space is no longer seen as an entire object -- one merely sees the separate piece focused upon

(Kaniza, 1976). In this case then, the closure figure should promote good performance when one must focus attention on one piece of information. Therefore, we believe the closure display will provide the best overall performance on all tasks. However, previous research has obtained mixed results on this issue. That is one of the reasons why we had three different closure groups, in which we manipulated the amount of space between the triangle vertices. Ultimately, we are trying to confirm that these closure displays are superior to other types of displays, as well as to determine how much space is required for the participant to have the highest possible performance on both tasks.

If you would like to read more about this sort of research, here are a few references:

- Carswell, C.M., & Wickens, C.D. (1987). Information integration and the object display: An integration of task demands and display superiority. *Ergonomics*, 30, 511-527.
- Kaniza, G. (1976). Subjective contours. In J.M. Wolfe (Ed.). *The Mind's Eye* (pp. 82-86). New York: W.H. Freeman and Company.
- Wickens, C.D., & Andre, A. (1990). Proximity compatibility and information display: Effects of color, space, and objectness on information integration. *Human Factors*, 32, 61-77.

### DEBRIEFING: 33% CLOSURE TRIANGLE DISPLAY

This study investigated how information should be visually presented to humans when they either have to take in different pieces of information at once (integrate) them or concentrate on one piece of information at a time (focused attention). Research studying the use of geometric objects to convey information for these tasks is known as “object display” research. A major result of this research has been that objects have “emergent features.” An emergent feature of a set of stimuli is what allows the set to be perceived as a whole unit. For example, one does not recognize a triangle by seeing the segments making up the legs, but rather by its more complex features (such as its area).

Enclosed objects such as a triangle promote good performance when sources of information must be integrated, such as estimating the likelihood of the existence of Schmelver’s Syndrome. However, the object display does not promote good performance when specific values must be identified, such as estimating the value of a single syndrome variable. Also, bar graphs have been shown to promote good performance on focused attention tasks, but not on integration tasks.

In our experiment, some students used a type of closure triangle, enclosed triangle, or a bar graph format. You were a member in what we call a “33% closure triangle” group. This means that the middle third of each side of the triangle was missing. We predicted that this display would enable you to answer both types of questions more quickly and accurately than the other displays.

The law is known as the Gestalt Law of Closure. This law states that incomplete contours are “filled in” by humans perceptually in order to see the space as an object (Koffka, 1935). Therefore, this display should promote good performance when one must integrate information. But, when one focuses on just one part of a closure figure, the space is no longer seen as an entire object -- one merely sees the separate piece focused upon (Kaniza, 1976). In this case then, the closure figure should promote good performance

when one must focus attention on one piece of information. Therefore, we believe the closure display will provide the best overall performance on all tasks. However, previous research has obtained mixed results on this issue. That is one of the reasons why we had three different closure groups, in which we manipulated the amount of space between the triangle vertices. Ultimately, we are trying to confirm that these closure displays are superior to other types of displays, as well as to determine how much space is required for the participant to have the highest possible performance on both tasks.

If you would like to read more about this sort of research, here are a few references:

- Carswell, C.M., & Wickens, C.D. (1987). Information integration and the object display: An integration of task demands and display superiority. *Ergonomics*, 30, 511-527.
- Kaniza, G. (1976). Subjective contours. In J.M. Wolfe (Ed.). *The Mind's Eye* (pp. 82-86). New York: W.H. Freeman and Company.
- Wickens, C.D., & Andre, A. (1990). Proximity compatibility and information display: Effects of color, space, and objectness on information integration. *Human Factors*, 32, 61-77.



### DEBRIEFING: 66% CLOSURE TRIANGLE DISPLAY

This study investigated how information should be visually presented to humans when they either have to take in different pieces of information at once (integrate) them or concentrate on one piece of information at a time (focused attention). Research studying the use of geometric objects to convey information for these tasks is known as “object display” research. A major result of this research has been that objects have “emergent features.” An emergent feature of a set of stimuli is what allows the set to be perceived as a whole unit. For example, one does not recognize a triangle by seeing the segments making up the legs, but rather by its more complex features (such as its area).

Enclosed objects such as triangle promote good performance when source of information must be integrated, such as estimating the likelihood of the existence of Schmelver’s Syndrome. However, the object display does not promote good performance when specific values must be identified, such as estimating the value of a single syndrome variable. Also, bar graphs have been shown to promote good performance on focused attention tasks, but not on integration tasks.

In our experiment, some students used a type of closure triangle, enclosed triangle, or a bar graph format. You, were a member in what we call a “66% closure triangle” group. This means that most of the sides were missing on your triangle. We predicted that having a larger space between vertices will promote better focused attention performance, because it will be easier to see the individual variables.

The law is known as the Gestalt Law of Closure. This law states that incomplete contours are “filled in” by humans perceptually in order to see the space as an object (Koffka, 1935). Therefore, this display should promote good performance when one must integrate information. But, when one focuses on just one part of a closure figure, the space is no longer seen as an entire object -- one merely sees the separate piece focused upon (Kaniza, 1976). In this case then, the closure figure should promote good performance

when one must focus attention on one piece of information. Therefore, we believe the closure display will provide the best overall performance on all tasks. However, previous research has obtained mixed results on this issue. That is one of the reasons why we had three different closure groups, in which we manipulated the amount of space between the triangle vertices. Ultimately, we are trying to confirm that these closure displays are superior to other types of displays, as well as to determine how much space is required for the participant to have the highest possible performance on both tasks.

If you would like to read more about this sort of research, here are a few references:

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